Capstone MicroTurbine
Model C65 Hybrid UPS
User's Manual

Capstone Turbine Corporation
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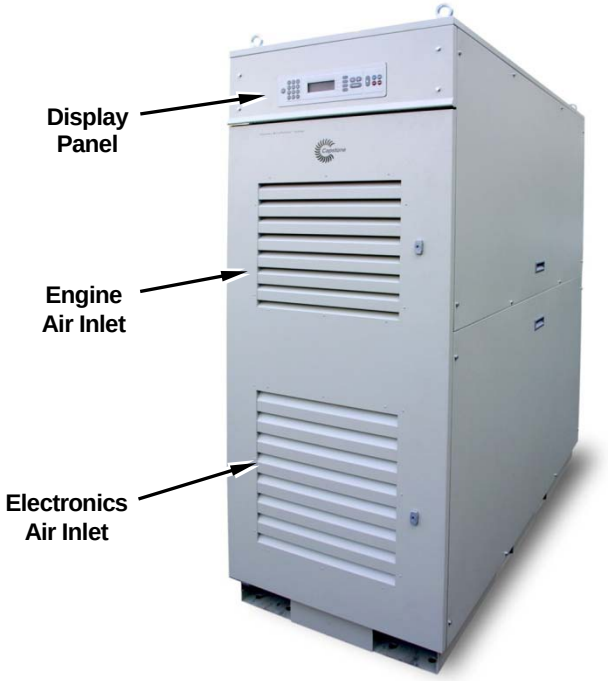
Welcome to the world of Capstone Power Generation!

We are pleased that you have chosen the Capstone MicroTurbine product for your application.



Model C65 Hybrid UPS Front View

Model C65 Hybrid UPS Rear View

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About This Document

This document provides user instructions to operate and maintain the Capstone Turbine Corporation Model C65 Hybrid UPS MicroTurbine. Basic troubleshooting is included in this manual, but only Capstone Authorized Service Providers are permitted to perform detailed troubleshooting and repair of the equipment.

This document is intended for user personnel who may not have specific training on the MicroTurbine (sometimes abbreviated as MT in this manual). Capstone Authorized Service Providers (ASPs) have received rigorous training and have been certified to perform commissioning, troubleshooting, and repair of the MicroTurbine. **User personnel who have not received certification of satisfactory completion of the Authorized Service Provider training should not attempt any procedures other than those specifically described in this document.**

For detailed technical data, or for service to the MicroTurbine, contact your Capstone Authorized Service Provider.

Safety Information

This section presents safety information for the user of Capstone Turbine Corporation MicroTurbines. The user must read and understand this manual before operation of the equipment. Failure to obey all safety precautions and general instructions may cause personal injury and/or damage to the equipment.

It is the user's responsibility to read and obey all safety procedures and to become familiar with these procedures and how to safely operate this equipment.

Introduction

The Capstone MicroTurbine is an advanced power generation system with user and material safety foremost in mind. Fail-safe operation includes mechanical systems, electrical systems, and engine control software.

Symbols

There are three very important symbols used in this document: Warnings, Cautions, and Notes. WARNINGs and CAUTIONs alert you to situations and procedures that can be dangerous to people and/or cause equipment damage. NOTEs provide additional information relating to a specific operation or task.

WARNING	A Warning means that personal injury or death is possible.

CAUTION	A Caution means that damage to the equipment is possible.

NOTE	A Note is used to clarify instructions or highlight information that might be overlooked.

General Precautions

The following general precautions must be observed and followed at all times. Failure to do so may result in personal injury and/or equipment damage.

NOTE	Some of the following precautions do not directly apply to users, but it is important for users to be aware of them.

- **Only Capstone Authorized Service Providers are permitted access to the inside of the enclosure.**
- Read and understand the User's Manual before operating the equipment.
- Read and obey all warnings and cautions.
- Make sure all fuel connections are tight, free from leaks, and protected from damage.
- Make sure all electrical connections are tight, clean, dry, and protected from weather and damage.
- The MicroTurbine may be equipped with a heat recovery system. Use caution around relief valves where hot water and steam may be present.
- Use hearing protection when you work on or near an operating MicroTurbine for extended time periods.
- The MicroTurbine is heavy. Be careful when you move or lift the MicroTurbine.
- Keep the equipment clean.
- Keep all flammable materials away from the MicroTurbine and its components.
- Do not operate or work on the equipment if mentally or physically impaired, or after consumption of alcohol or drugs.
- Make sure all fasteners are installed and properly tightened.
- Keep an ABC rated fire extinguisher near the MicroTurbine.
- Obey all applicable local, state, and national codes and regulations.

Electrical Precautions

WARNING	The MicroTurbine system contains and produces high voltage. High voltage can injure or kill. Obey all safety procedures when you work around electrical equipment.

WARNING	Make sure the system is off and the dedicated disconnect switch is in the open position and is locked. This will help prevent injury and damage to the equipment.

NOTE	Some of the following precautions do not directly apply to users, but it is important for users to be aware of them.

The output voltage and residual capacitor voltage of this equipment is dangerous. Use caution when you work on electrical equipment. The MicroTurbine system can include multiple sources of power. Make sure to turn off the system and lock out all sources of power prior to doing any work on the equipment.

- Command the MicroTurbine system to OFF.
- Open and lock the dedicated disconnect switches to isolate the MicroTurbine from the electric utility grid, external energy storage, and loads.
- Wait five (5) minutes for any capacitive stored voltage to dissipate.
- Always disconnect all power sources.
- Use a voltmeter to make sure that all circuits are de-energized.
- All output connections must be made in accordance with applicable codes.

Fuel Precautions

WARNING	MicroTurbine fuel is flammable and explosive. An explosion can cause death or injury to personnel and/or damage to equipment. No open flame or smoking is allowed near the MicroTurbine.

WARNING	Gaseous fuels can be corrosive. Injury to personnel and/or damage to equipment can occur. Minimize exposure to gaseous fuels and provide satisfactory fresh airflow when you are around equipment.

The Capstone MicroTurbine operates on approved gaseous fuels. Keep flames, sparks, pilot lights, equipment that produces electrical arcs, switches or tools, and all other sources of ignition away from areas where fuel and fumes are present. If there is a fire, use a multi-purpose dry chemical or CO2 fire extinguisher, and contact the appropriate fire officials.

Fuel lines must be secure and free of leaks. Fuel lines must also be separated or shielded from electrical wiring. If you smell fuel fumes, immediately stop operation of the equipment, close the fuel isolation valve, and locate and repair the source of the leak or call a qualified professional.

Exhaust Precautions

WARNING	The MicroTurbine exhaust contains nitrogen dioxide and carbon monoxide, which are poisonous at high concentrations. Make sure there is satisfactory fresh airflow when you work around the equipment.

WARNING	The exhaust airflow and pipes are hot enough to cause personal injury or fire. The exhaust airflow can reach temperatures as high as 371 °C (700 °F). Keep people, equipment, and other items away from the exhaust airflow and pipes. Always vent exhaust away from personnel.

WARNING	Hot surfaces and hot exhaust can be dangerous. Personal injury and/or damage to equipment are possible. Be careful when you work on equipment.

The MicroTurbine exhaust is clean and oxygen rich (approximately 18% O_2), with very low levels of air pollutants. Like all fossil fuel combustion technologies, the MicroTurbine produces oxides of nitrogen (NOx) and carbon monoxide (CO) emissions from the fuel combustion process. Although the MicroTurbine has ultra low NOx and CO emission levels, make sure precautions are taken to prevent personnel from being exposed to these pollutants while the system is operating.

When installed indoors, the MicroTurbine exhaust must be vented to the outside. Make sure there is a satisfactory fresh air supply. An exhaust system must be added to direct the exhaust away from the system to reduce the risk of exposure to dangerous emissions.

For exhaust connection data, temperatures, pipe requirements, and other related information, contact your Capstone Authorized Service Provider.

When installed outdoors, the MicroTurbine should be located where there is a satisfactory fresh airflow so the exhaust emissions will be dissipated.

Acoustic Emissions Precautions

The Capstone MicroTurbine is designed to produce safe acoustic emissions. However, when working at a radius of 10 meters (or 33 feet) from an enclosed Capstone MicroTurbine, sound level exposure will average approximately 70 dBA.

Capstone recommends that hearing protection be worn when working on or in the immediate vicinity of operating MicroTurbines for extended time periods.

Other acoustic emissions regulations may apply to your specific installation location. Always check to be certain that your installation complies with all codes required by the local jurisdiction.

Certifications, Permits, and Codes

Your Capstone MicroTurbine is designed and manufactured in accordance with a variety of national and international standards.

The Capstone MicroTurbine operates on approved gaseous fuels; thus installation frequently requires one or more permits from local regulatory agencies.

It is not practical to list in the User's Manual the requirements of each authority having jurisdiction and how the Capstone MicroTurbine meets those requirements. For certification data, such as weights, dimensions, required clearances, noise levels, and the Capstone MicroTurbine Compliance List, please contact your Capstone Authorized Service Provider.

MicroTurbine Introduction

The Capstone MicroTurbine is an adaptable, low-emission, and low maintenance power generation system. A turbine-driven high-speed generator is coupled with digital power electronics to produce high quality electrical power.

The Capstone Hybrid UPS MicroTurbine uses a proprietary design that provides high quality power to customer loads using a utility grid source, the turbine generator, or both. This allows users to optimize energy costs while assuring that their critical loads will receive continuous power.

Multiple systems can be combined and controlled as a single larger power source, called a MultiPac.

The MicroTurbine can efficiently use a wide range of approved hydrocarbon-based gaseous fuels.

The MicroTurbine produces dry, oxygen-rich exhaust with ultra-low emissions. Utilizing both the generated electric power and the exhaust heat can provide even greater energy cost savings.

Key Mechanical Components

The key mechanical components that make up the Capstone MicroTurbine are shown in Figure 1.

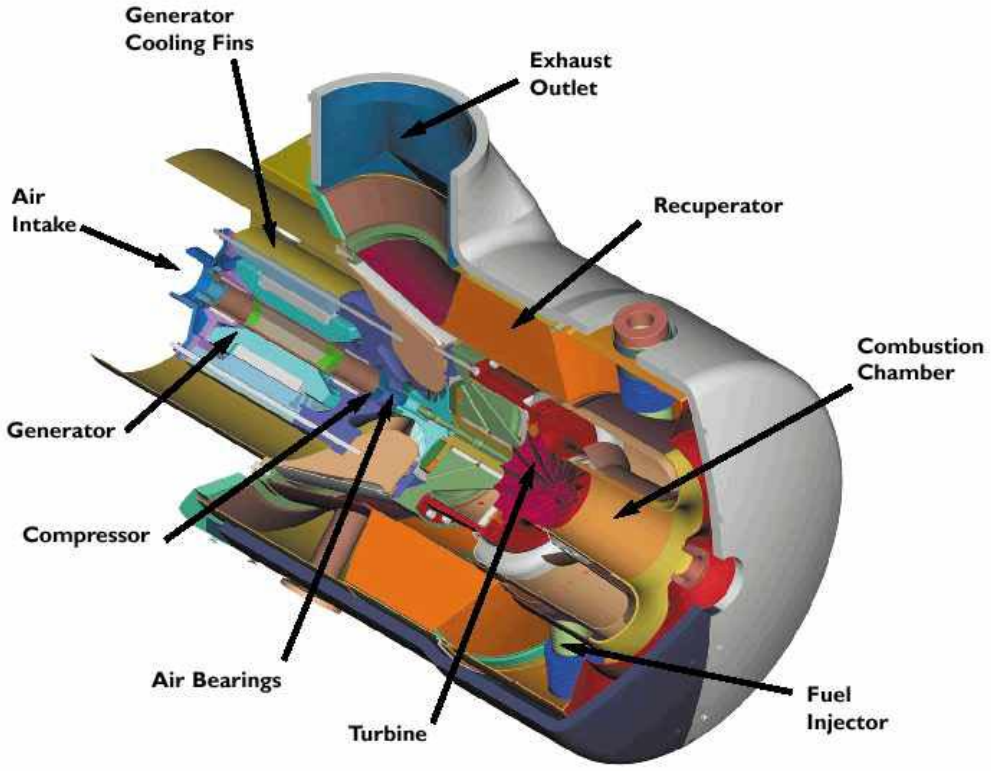


Figure 1. Typical Capstone MicroTurbine Engine

Main Features

The various features of the Capstone Hybrid UPS MicroTurbine are listed below:

- State-of-the-art power electronics with built-in control and protective relay functions provides three user connections:
  - Utility Input (AC)
  - Load Output (AC)
  - External Energy Storage (DC)
- Patented air bearings eliminate the need for oil or other liquid lubricants.
- Air-cooled design of the entire system (turbine engine, generator, and power electronics) eliminates the need for liquid coolants.

- Only one moving part. No gears, belts, or turbine-driven accessories.
- Advanced combustion control provides ultra-low emissions.
- The integral annular recuperator (heat exchanger) doubles thermal efficiency.
- Digital control technology facilitates advanced control and diagnostic capabilities, both on-board and remotely.

MicroTurbine Engine

The MicroTurbine engine is a combustion turbine that includes a compressor, combustor, turbine, generator, and a recuperator. The rotating components are mounted on a single shaft supported by patented air bearings and spin at up to 96,000 RPM. The permanent magnet generator is cooled by the airflow into the MicroTurbine. The output of the generator is variable voltage, variable frequency AC. The generator is used as a motor during start-up and cooldown cycles.

Power Electronics

Digital power electronics control the MicroTurbine system operation and all subsystem operations. The digital power electronics change the variable frequency AC power from the generator to DC voltage, and then to constant frequency AC current.

During start up, the digital power electronics operate as a variable frequency drive, driving the generator as a motor until the MicroTurbine has reached ignition and power is available from the MicroTurbine. The digital power electronics again operate the generator as a motor during cooldown to remove heat stored in the recuperator and within the MicroTurbine engine in order to protect the system components.

Air Bearings

The MicroTurbine utilizes gas foil bearings (air bearings) for high-reliability, low maintenance, and safe operation. This allows fewer parts and the absence of any liquid lubrication to support the rotating group. When the MicroTurbine is in operation, a gas film separates the shaft from the bearings and protects them from wear.

Fuel System

The MicroTurbine can efficiently use a wide range of approved hydrocarbon-based gaseous fuels, depending on the model. The MicroTurbine includes an integral fuel delivery and control system. The standard system is designed for pressurized hydrocarbon-based gaseous fuels. Other models are available for low-pressure gaseous fuels and liquid fuels. Contact your Capstone Authorized Service Provider for data on approved fuels and performance specifications.

Emissions

The Capstone MicroTurbine is designed to produce very clean emissions. The exhaust is clean and oxygen rich (approximately 18% O_2) with very low levels of air pollutants. Like all fuel combustion technology, the MicroTurbine can produce dangerous emissions (like nitrogen dioxide and carbon monoxide) from the fuel combustion process. The MicroTurbine has ultra low nitrogen dioxide (NO_2) and carbon monoxide (CO) emission levels.

Enclosure

The MicroTurbine standard enclosure is designed for indoor and outdoor use, and is certified to NEMA 3R - rainproof.

Hybrid UPS Functionality

The C65 Hybrid UPS MicroTurbine can operate in several modes:

- UPS Mode – in this operating state, the Hybrid UPS system takes power from the utility and provides conditioned output power to the load, similar to a traditional double-conversion UPS system.
- High Efficiency Mode – in this mode, the C65 turbine generator provides power to offset the need for utility input power. By utilizing the microturbine's clean exhaust energy for heating or absorption cooling, extremely high energy utilization is achieved to reduce operating costs, reduce net energy consumption, and reduce overall emissions of greenhouse gas and criteria pollutants.
- Emergency Mode – if utility power becomes unavailable, the Hybrid UPS system will continue to provide power to the critical load using its external energy storage. The turbine generator will automatically start to cover extended outages.

The Hybrid UPS system output will maintain synchronism with the utility grid whenever a stable grid is available. A full description of the modes of operation is provided in the Hybrid UPS Operating Modes section below.

UPS Controller

Capstone Hybrid UPS systems are designed to be controlled by an external accessory called the UPS Controller. The UPS Controller acts as a master, providing control commands to each Hybrid UPS system, reading performance and diagnostic data from each system, and acting as the user interface. The UPS Controller can manage up to 10 Hybrid UPS systems, and operates all connected microturbines as a single power generation source. Additional details are provided in the Operating the Hybrid UPS System section below.

MultiPac Power

Capstone Hybrid UPS MicroTurbines can be installed in groups of up to 10 units using Capstone's UPS Controller as a master. The UPS Controller operates all connected microturbines as a single power generation source. This MultiPac capability features a single control point and synchronous voltage and frequency output for all units. Individual MicroTurbines share power, current, and load on both a dynamic and steady state basis.

Integrated Combined Heating and Power (ICHP) Option

The Integrated Combined Heating and Power (ICHP) option allows the user to realize the benefits of usable electrical and thermal power from a single fuel source. The Hybrid UPS ICHP system provides high efficiency on-site power generation in conjunction with local utility power. The heat offsets or replaces local thermal loads such as space heating, industrial process hot water, or to drive an absorption chiller.

The major system components are a Capstone model C65 high-pressure natural gas MicroTurbine, an exhaust heat recovery unit, and an exhaust diverter to allow full or partial recovery of exhaust energy. The system includes microprocessor control with input/output functions to allow application in a wide variety of heat recovery uses. The system allows a user to realize high total system efficiency with respect to incoming fuel energy, providing economical operation and operational flexibility.

Output Measurements

The measurements presented in this document are in metric units (with U.S. standard units in parentheses). Refer to the sections below for more data.

ISO Conditions

Combustion turbine powered devices (including the Capstone MicroTurbine) are typically rated at 15 °C (59 °F) at sea level, or 1 atmosphere (1 atm) which is 760 mm Hg (14.696 psia) and identified as International Standardization Organization (ISO) conditions. For a complete definition of ISO testing conditions, refer to ISO 3977-2.

Pressure

Pressure figures assume gauge pressure, or 1 standard atmosphere (1 atm) 760 mm Hg (14.696 psia) less than absolute pressure, unless otherwise indicated.

Volume

Fuel gas and exhaust gas volumetric measurements are listed in normalized cubic meters (Nm^3) and standard cubic feet (scf). These volumes are defined at 1 atm (760 mm Hg, 14.696 psia) and 15.6 °C (60 °F).

Heating Values

Heat contents and heat rates will be found in either Lower Heating Value (LHV) (dry) or Higher Heating Value (HHV), depending upon the application. Capstone calculates heating values at 1 atmosphere (atm) and 15.6 °C (60 °F), according to ASTM D3588.

MicroTurbine Performance

The MicroTurbine electrical output capability is reduced when operating in higher ambient temperatures or elevations, and by intake or exhaust restrictions. Refer to the C65 Performance Technical Reference (410048), or contact your Capstone Authorized Service Provider for data on performance specifications.

Utility Input Connection

The Hybrid UPS MicroTurbine electrical connection to a utility source is 3-phase, 400 to 480 VAC and 45 to 65 Hz (both voltage and frequency are determined by the electric utility grid). Allowable connection is 4-wire Wye. An isolation transformer may be required, depending on the system configuration.

Load Output Connection

The Hybrid UPS MicroTurbine's electrical output to the critical load will automatically be adjusted to match stable incoming utility grid power in both frequency and phase relationship. Output voltage will be maintained at a preset value, regardless of incoming utility voltage.

The maximum power need not be balanced. Loads can be connected 3 phases or single phase and phase-to-phase or phase-to-neutral, so long as the current limits are respected. An isolation transformer may be required, depending on the system configuration.

When utility voltage is unavailable, the output to the critical load will operate at the selected voltage and frequency until the utility grid voltage returns and is stable. The Hybrid UPS system will then automatically adjust its frequency and phase relationship to match the utility again.

Power Quality

The MicroTurbine output conforms to IEEE 519-1992, IEEE Recommended Practices, and Requirements for Harmonic Control in Electrical Power Systems.

Heat Output

The recuperated MicroTurbine can produce up to 612,000 kJ (580,000 Btu) per hour of clean, usable exhaust heat in the range of 232 to 330 °C (450 to 630 °F).

The MicroTurbine exhaust outlet connection is 305 mm (12 in) in diameter, flowing up to 28 m^3 (2600 scf) per minute.

Refer to the C65 Integrated CHP Application Guide (480014), or contact your Capstone Authorized Service Provider for data on heat output performance for specific system variations and/or ambient conditions.

Hybrid UPS System Operating Modes

This section explains the different operating modes of the Capstone Hybrid UPS MicroTurbine and how the system transitions between operating states. A description of the major system components is provided to clarify the terminology and understanding of how the system works.

Major System Components

The C65 Hybrid UPS system is based on the Dual Mode C65 MicroTurbine, with the addition of a second Load Control Module (LCM) to allow load power to be provided by a utility grid, the turbine generator, or both. Figure 2 shows the major components in a single C65 Hybrid UPS system.

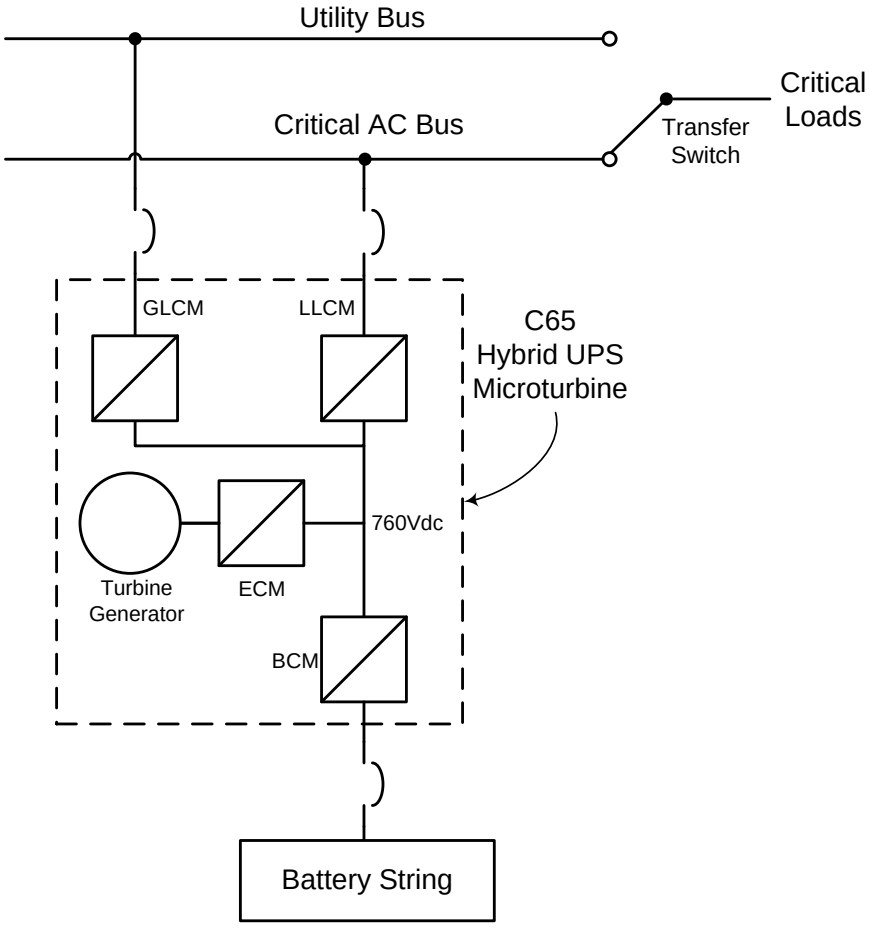


Figure 2. Major Components of C65 Hybrid UPS System

Grid LCM (GLCM)

The GLCM connects to the normal utility grid power, and converts AC power for connection to the internal 760V DC bus. The GLCM is bi-directional, and power can flow either to or from the utility grid. The GLCM has its own protective relay functions that monitor the stability of the utility bus voltage, and it will automatically disconnect power from an unstable grid. When it has disconnected power from the grid, the GLCM continues to monitor the grid voltage. If the engine has not been commanded to start, the GLCM will reconnect power without delay when the grid returns to a stable condition. If the engine is running or is in a start sequence, the GLCM will reconnect power when the grid has remained stable for a user-defined reconnection delay period.

Load LCM (LLCM)

The LLCM takes power from the internal 760 VDC bus to the customer's critical load. The LLCM is unidirectional, and power will only flow from the internal DC bus to the critical load. It will maintain the frequency and phase angle of its output to match the utility grid voltage sensed by the GLCM whenever the utility voltage is stable, and will revert to a preset frequency when the utility voltage is unavailable. The LLCM will provide a preset voltage output to power the critical loads. Protective relay functions are also integrated into the LLCM to protect against disturbances on the load output.

Battery Control Module (BCM)

The BCM converts the battery string voltage to the internal 760 VDC. It is able to import full power to the Hybrid UPS system from an external energy storage system (typically a battery string), and can also export power to an individual energy storage system connected to only one microturbine for recharging.

Battery String

The battery string can be a battery bank or other energy storage system, either supplied by Capstone or the customer. It will typically be sized for at least 15 minutes of full power capability so that it can provide power to the protected load while a non-operating turbine generator is started.

The Hybrid UPS MicroTurbine must be connected to an external battery or other storage system which provides energy for MT startup when disconnected from the electric utility grid, and which provides temporary power when utility power suddenly becomes unavailable.

For external battery systems sold as an accessory by Capstone, management of the battery and its state of charge is automatic between the Hybrid UPS microturbine and the external battery pack. An awareness of these battery management functions will promote an understanding of why the system may appear to behave autonomously. For example, the MicroTurbine will always attempt to recharge the battery after a user commanded shut down and before the MicroTurbine enters the cool down state.

For battery storage systems provided by others, a separate battery management and charging system must be provided. The Hybrid UPS system will not provide any battery management, condition monitoring, or charging. An indication of battery state of charge must be provided through the UPS Controller. Contact Capstone for application guidance.

Engine Control Module (ECM)

The ECM connects the high speed turbine generator output to the internal 760V DC bus. It is bi-directional, and power is taken from the DC bus to start the turbine. During operation, the turbine generator speed is independent from the utility input or load output frequencies. The ECM includes all the logic for operating the turbine generator, as well as resistive energy dissipation capability to absorb turbine power in case of sudden load loss.

Turbine Generator

The Capstone turbine generator uses fuel input to create useful high-frequency AC electrical output, which is converted by the ECM to DC for distribution to the remainder of the Hybrid UPS system. Power from the turbine is used for the critical load output, with any excess going back through the GLCM to the utility grid and/or through the BCM to recharge the batteries.

Transfer Switch

Typically, a transfer switch or other load transfer scheme will be supplied by others to allow power to be fed to the critical loads directly by the Utility bus in case there is a problem with the Hybrid UPS system. Since the Hybrid UPS system will always try to maintain synchronism of its load output to the utility input, a closed transition transfer switch scheme can be used to minimize voltage disturbances to the critical loads.

UPS Mode

The Hybrid UPS MicroTurbine can take power from a utility grid and make it available to the critical loads through a double power conversion process, similar to the way a traditional UPS operates. The output power to the critical loads is isolated from disturbances on the utility grid, and its power quality is maintained. In UPS Mode, the turbine generator is not operating, and the output power is supplied only by the utility grid input from the GLCM through to the LLCM. The frequency of the output to the critical load is determined by the utility grid, and the phase relationship is maintained between input and output of the Hybrid UPS system. The desired voltage to the critical load is pre-set by the user, and the Hybrid UPS system will attempt to maintain this pre-set value even if utility voltage varies.

High Efficiency Mode

The High Efficiency Mode of operation allows the microturbine to generate its' own power to supplement the utility grid. The power it generates can be set at more or less than the amount of power the critical loads require, with the utility grid connection automatically taking or giving the difference as required. The system must be actively connected to a stable utility grid source for it to enter the High Efficiency Mode. High Efficiency Mode can therefore be thought of as a special case of UPS Mode, where the turbine has been commanded ON and operates in parallel with the Utility grid.

Emergency Mode

The Hybrid UPS system will automatically transition to the Emergency Mode if commanded to operate in either UPS Mode or High Efficiency Mode and utility power is unavailable. Emergency Mode cannot be selected as a desired operating state. In Emergency Mode, power is supplied to the critical load from either the external batteries and/or the turbine generator. An external battery energy source must be available for the system to operate in Emergency Mode.

Standby Mode

In Standby Mode, the Hybrid UPS system is completely taken out of service and shut down. No power is taken from the utility grid, or provided to the load output, and the turbine generator is off. If left in this state for an extended period of time, the system will also attempt to preserve energy storage life by entering a sleep mode to reduce power requirements, and the Display Panel will go dark. This is the condition the Hybrid UPS system will be in when shipped from the factory.

States versus Operating Modes

In the Hybrid UPS system, there are both Systems States as well as Engine States, which together determine the Mode of Operation. Figure 3 provides an overview of the general flow of System and Engine States from one commanded Operating Mode to another.

Transition States

The user can command the Hybrid UPS microturbines to be in UPS Mode, High Efficiency Mode, or Standby Mode. However, there are certain required conditions for the system to enter any of these operating modes, and it will transition through multiple states in order to reach the desired operating mode. Emergency Mode is not a user-commanded operating state, but rather is the result of the system being commanded to operate in UPS Mode or High Efficiency Mode when the utility grid is unavailable.

Elements Impacting Transitions

The major elements that impact these transitions between states are:

Battery SOC

If the battery state of charge is below some preset limit (for example 50% SOC), the turbine may need to be started to allow transition into the next operating state. This is because the Hybrid UPS system should always be capable of continuing to power the critical load once it starts to provide power. If the battery SOC is too low, there may not be sufficient energy to maintain power in Emergency Mode should the utility suddenly become unavailable.

For Hybrid UPS systems with external battery systems provided by others, the Capstone UPS Controller must receive ongoing state of charge information. The UPS Controller will then assure the proper transition sequence. Consult Capstone for how their individual battery packs will provide this SOC information to the Hybrid UPS systems.

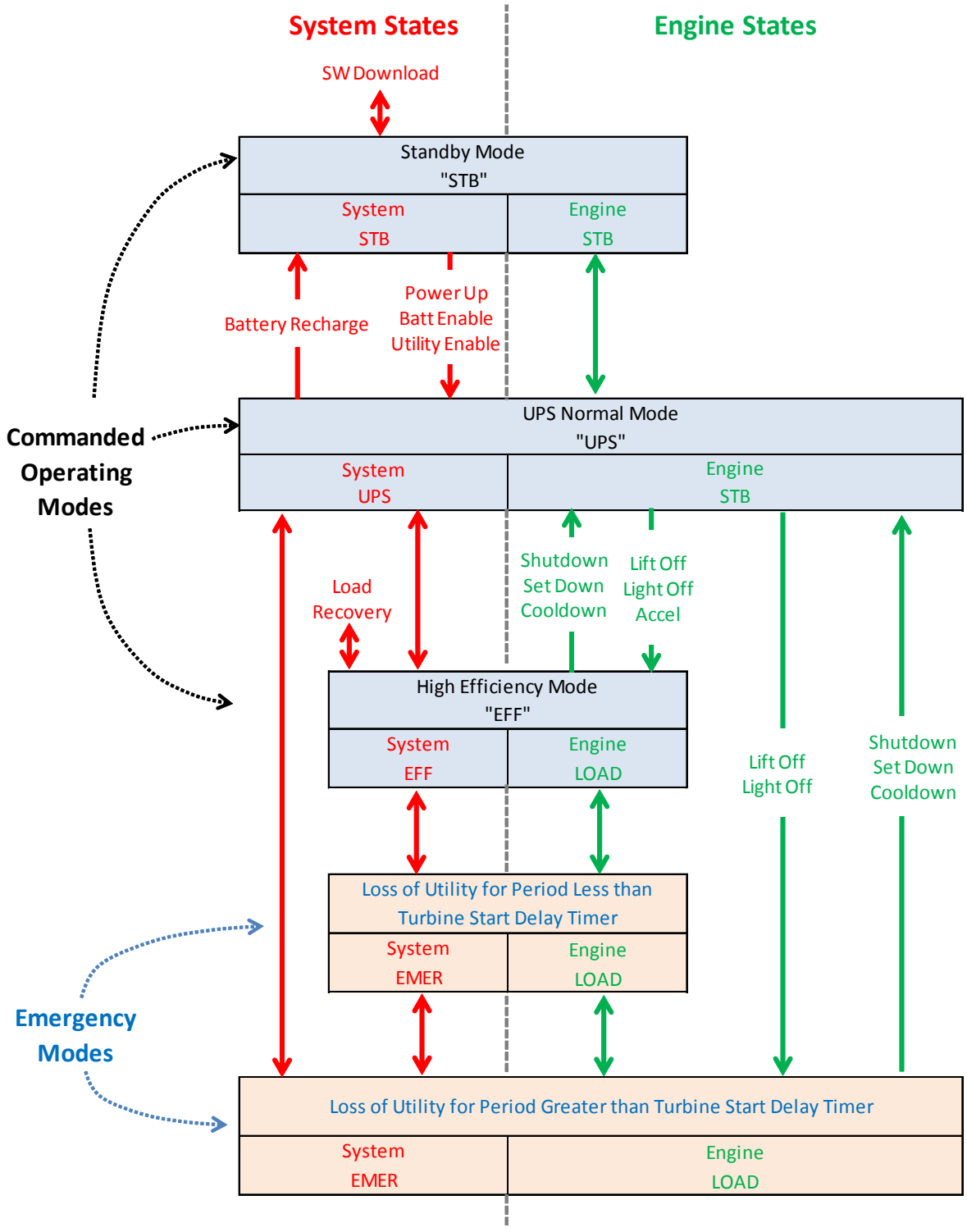


Figure 3. States versus Operating Modes

Utility Voltage

Utility voltage must be present and within the GLCM's utility input protective relay settings to allow the system to operate in UPS Mode or High Efficiency Mode. Conversely, loss of stable utility voltage will automatically trigger the GLCM to disconnect utility power and force the Hybrid UPS system into Emergency Mode.

Utility Reconnect Delay

Once the Hybrid UPS system has been disconnected from the utility for any reason, it must go through a reconnect sequence whenever the turbine is running or has already entered a start sequence. This is a requirement of IEEE 1547, UL 1741, and most electric utilities, and is intended to prevent inadvertent energizing of an unstable utility grid. The system must wait for the utility voltage to remain within the protective relay settings for the set reconnect delay time (5 to 30 minutes) before the Hybrid UPS system can close its internal power connection to the utility grid. The GLCM is constantly monitoring the utility voltage whenever it is not in Standby Mode, and will start the reconnect delay timer whenever it senses stable conditions. Therefore, there may or may not be a state transition delay in connecting to utility power, depending on the timing of events leading up to the Hybrid UPS system attempting to reconnect to the utility grid.

UPS Mode vs High Efficiency Mode

If the system in enabled in UPS Mode, it will not try to start the turbine unless there is some other reason to do so (like low battery state of charge). If the system is enabled in High Efficiency Mode, it will always try to run the turbine unless there is some reason it cannot (such as lack of fuel). Therefore, the selected mode of operation will have an impact on what states the system transitions through to get to the desired mode.

Turbine Start Delay Timer

The Hybrid UPS systems include a turbine generator start delay timer to prevent systems operating in UPS Mode from immediately starting their engines for every utility disturbance condition. The timer is user adjustable from 0 to 10 minutes, during which time the system waits for return of stable utility voltage. If utility voltage returns to a stable condition before the end of this time, the turbine generator will not be started and the GLCM will immediately reconnect utility power. If utility voltage does not return to within the programmed GLCM protective relay limits before the end of this time, the turbine generator will be started. Once the turbine start command has been issued, the system must wait for utility voltage to return, and then pass through the utility reconnect delay sequence before reconnecting utility power to the GLCM. The system will then issue a stop command to the turbine generator once battery state of charge is above a preset level.

MultiPac Minimum Power

Hybrid UPS systems will normally be operating as part of a MultiPac in order to achieve at least n+1 availability at all times. When operating in a MultiPac, the control system will check to confirm that there are a sufficient number of Hybrid UPS systems available to provide the preset minimum power demand before the LLCM's will be commanded to provide power to the load during startup. Therefore, if some units become unavailable for any reason:

- There can be a delay waiting for sufficient systems to meet the preset Minimum Power Demand, and
- The entire MultiPac system will shut down if the Minimum Power Timeout Period is reached before sufficient systems become available.

System Start Sequences

When commanded to start from Standby Mode, there are several sequences that can result, depending on the desired UPS or High Efficiency Mode and the conditions noted above. Table 1 shows eight possible start sequences. Only start sequence 1 will immediately bring power to the critical load and immediately connect to the utility. All other sequences result in an engine start, and subsequent utility reconnection delay. While the battery state of charge will have an impact on whether the turbine is started or not, reconnection to the Utility grid does not depend on it. This is because there will be more power available for recharging when both utility and turbine are available. Note that the battery SOC of 50% can be adjusted to more or less, depending on the customer application, and is shown in the table for purposes of explanation. If the battery system is provided by others, the UPS Controller may not use state of charge from this external system to provide the logic and permissive signals to the Hybrid UPS microturbines to start and stop turbines as shown in Table 1, and therefore assumes sufficient SOC.

Table 1. System Start Sequences

Hybrid UPS Mode	Start Sequence Scenario	Battery SOC	Utility Voltage	Turbine Start	Load Connection		Utility Connection			Turbine Stop	
					No Wait	Wait for Turbine Start	No Wait	Wait for		No Wait	Wait for Battery SOC >50%
								Utility Voltage OK	Utility Reconnect Delay		
UPS	1	>50%	OK		X		X				
	2	>50%	Not OK	X		X		X	X	X	
	3	<50%	OK	X		X			X		X
	4	<50%	Not OK	X		X		X	X		X
Hi Eff	5	>50%	OK	X	X				X	Turbine Keeps Running	
	6	>50%	Not OK	X		X		X	X		
	7	<50%	OK	X		X			X		
	8	<50%	Not OK	X		X		X	X		

Transitions to/from Emergency Mode

Once the system is operating, loss of utility power will automatically transition the system into Emergency Mode. Loss of utility power is any condition that causes the utility grid protective relay functions to operate. The Hybrid UPS system will always attempt to power the critical load once the system has completed its start sequence, unless some condition causes a complete shutdown (for example, a severe fault on the critical load bus). Table 2 shows four possible scenarios that can occur if utility power is outside of the preset protective relay limits. Note that scenario 1 is the only condition where reconnection to the utility will occur as soon as the utility voltage is back within limits. All other scenarios involve starting a turbine or keeping a turbine running, and therefore the system must wait for the utility grid reconnect delay. While the battery state of charge will have an impact on whether the turbine is started or not, reconnection to the Utility grid does not depend on it. For systems enabled in the UPS Mode, the turbine will continue operating until battery SOC is above the preset limit before being shut down. If the battery system is provided by others, the UPS Controller may read state of charge from this external system and provide the logic and permissive signals to the Hybrid UPS microturbines to start and stop turbines as shown in Table 2.

Table 2. System Transitions to/from Emergency Mode

Hybrid UPS Mode	Utility Loss Scenario	Battery SOC	Turbine Start Delay Timeout	Turbine Start or Already Running	Utility Reconnection wait for		Turbine Stop	
					Utility Voltage OK	Utility Reconnect Delay	No Wait	Wait for Battery SOC >50%
UPS	1	>50%	NO	NO	X			
	2	>50%	YES	YES	X	X	X	
	3	<50%	YES or NO	YES	X	X		X
Hi Eff	4	ANY	N/A	RUNNING	X	X	Turbine Keeps Running	

The normal scenario for transition to and from Emergency Mode is loss of utility voltage sensed at the incoming connection of all Hybrid UPS system in a group, with the result that all Hybrid UPS systems enter Emergency Mode. However, it is also possible that an individual Hybrid UPS system will respond to a utility grid disturbance, or detect an internal fault condition, and will automatically transition to Emergency Mode while the remaining Hybrid UPS systems stay in UPS Mode or High Efficiency Mode. This provides for maximum availability of power to the critical load bus. The individual Hybrid UPS system will then either automatically transition back to UPS or High Efficiency Mode as shown in Table 2, or if an internal fault caused the transition, will continue operating in Emergency Mode until operator intervention corrects the problem.

NOTE	It is possible to have one or more Hybrid UPS system in Emergency Mode while other systems are in UPS or High Efficiency Mode. Power to the critical load will be shared equally among all Hybrid UPS systems in a MultiPac, regardless of the operating mode of each individual system.

Operating the Hybrid UPS System

Typical operation of the Hybrid UPS MicroTurbine system is presented in this section. Most applications require no regular interaction with an operator during normal operation. The basic operating functions are described in the subsections below, including typical operating scenarios.

Three User Interfaces

There are three user interfaces to the Hybrid UPS system, each with its own purpose and functionality for enabling system operation. Refer to Table 3 for a summary of the capabilities of each.

Table 3. User Interface Capabilities

User Interface	Control System		Display Data	Configure Settings	Download Software	Interface to BMS
	MultiPac	Single				
UPS Controller	X	X	X			X
Display Panel		X	X	limited		
PC with CRMS		X	X	X	X	

Operation of the Hybrid UPS system uses the above capabilities for the following purposes:

- UPS Controller – required for operation and control of more than a single microturbine and provides communications interface to building management system or other external control equipment.
- Display Panel – useful for data and status display and limited service functions.
- PC with CRMS – required for initial system configuration and full service functions. Can also provide remote user monitoring through the UPS Controller.

Control Device Authority and Priority

The three user interfaces have different control priorities as follows.

- UPS Controller – this is the Master control device for the MultiPac, and it takes priority over the Hybrid UPS system's local Display Panel as well as a PC connected to the UPS Controller and operating the User Edition of CRMS software. The UPS Controller is connected to each Hybrid UPS system using the MultiPac Ethernet coax cable, as well as to the User and Maintenance Ports through the serial-to-Ethernet converters in each unit. The user can view selected data for each unit in the MultiPac without requiring a password. Changes to the operating mode are password protected.
- Display Panel – the local Display panel on the Hybrid UPS system has limited control capability. As with any Capstone MicroTurbine, the few control functions it does offer will not be available when the Hybrid UPS system is operating as part of a MultiPac, including the ability to start and stop the system. Once operating as an individual unit, some additional control commands become available. Note that the Display Panel will show whether the Display Panel itself, the User Port, or the Maintenance Port has control access.

CAUTION	Using CRMS to request data faster than every 2 seconds may interfere with operation of the UPS Controller causing inadvertent operation or shutdown of the Hybrid UPS systems. Do not set any CRMS Data Acquisition or Record to File timers less than 2 seconds.

- PC with CRMS Software – the CRMS software provides the capability for a PC to connect to each Hybrid UPS system, either through the Ethernet connection in the UPS Controller or while plugged directly into a unit using the Ethernet port on the serial-to-Ethernet converter. The converter provides connectivity to both the User and Maintenance Interface Ports. The User Port is reserved for communications with the UPS Controller, and the Maintenance Port is for CRMS. Refer to the CRMS User Manual (410013) for additional information.

Initial Setup and Commissioning

Configuration and commissioning of a Hybrid UPS system requires a Capstone Authorized Service Provider using a PC with CRMS software. Once the Hybrid UPS system has been properly configured with all protective relay, communications, and other basic setup information, there should be no need to change this information during normal operation. All configuration data is stored in non-volatile memory in the Hybrid UPS systems themselves, as well as the UPS Controller, so loss of power will not prevent proper restarting of a system if required.

As part of the commissioning process, your service provider will start the system and provide specific instructions on user operation and maintenance. Consult your Capstone Authorized Service Provider if the system is not operating as expected or requires a change to one or more configuration parameters.

System Start-up

A MultiPac of Hybrid UPS system requires a UPS Controller to act as a master, and the UPS Controller provides the user interface to transition the system from a Standby Mode to either UPS Mode or High Efficiency Mode. In order to start, the Hybrid UPS systems must be connected to an external energy storage system, either individually or through a common DC bus. If the UPS Controller has lost power for an extended period, its' internal UPS system will automatically go into a sleep mode to preserve power for just such a start attempt. The integral touch screen display on the UPS Controller will likewise go blank if there has been no user interaction for a preset time delay. The UPS controller provides several means to start the system:

- UPS Controller Touch Screen Display – If the touch screen display panel is dark, touch it anywhere to activate it. If it does not light up within a few seconds, the internal UPS system may have gone to sleep, and will require the user to press the System Wake button on the front of the UPS Controller. When the screen becomes active, follow the menu structure to start the system in either UPS Mode or High Efficiency Mode.
- UPS Controller BMS Interface – the UPS Controller is able to communicate with a building management system or other external control equipment, and receive a remote start command. The UPS Controller includes a "System OK" discrete output that should be read by the BMS system and included in its' logic for issuing commands to the UPS Controller. If the BMS does not receive a System OK

signal, it may be due to the UPS system in the UPS Controller being in sleep mode. A discrete System Wake input line from the BMS can then be switched on to wake the UPS Controller, which can then accept the appropriate system start and mode control commands. Instructions on use of the BMS to manually control the UPS Controller should be provided by others.

When a Start command is issued to the UPS Controller, it will proceed through transition states to ultimately enter the desired UPS Mode or High Efficiency Mode, as described in the Hybrid UPS System Operating Modes section above.

Routine Operation

Once the Hybrid UPS system has been started, it should not require any regular interaction with an operator during normal operation. If utility power becomes unavailable, the system will automatically switch to Emergency Mode and continue to supply power to the critical loads using power from the external battery storage and/or the microturbine generators themselves. When utility power returns to normal, the system will automatically reconnect and turn off microturbine generators as needed. The transition states to return to the desired UPS Mode or High Efficiency Mode are described in the Hybrid UPS System Operating Modes section above.

The UPS Controller also provides an interface to a building management system or other external control system to command operation in either UPS Mode or High Efficiency Mode. When operating in High Efficiency Mode, the external control system will also tell the UPS Controller what power level is needed, and the Hybrid UPS MicroTurbine generators will then adjust their power output to meet this demand. No manual operator intervention is normally needed.

Changing Operating Modes

The UPS Controller must be told what the desired operating mode is; either UPS Mode or High Efficiency Mode. This must be done through the UPS Controller, and can be automated (as described in the Routine Operation subsection above), or done manually either using the UPS Controller display or using controls integrated into the building management system. The UPS controller provides several means to change the operating mode of a running system:

- UPS Controller Touch Screen Display – If the touch screen display panel is dark, touch it anywhere to activate it. Enter the Maintenance screen using password, and select either Local/Standby or Remote. In Remote setting, the UPS Controller requires external input from a building management system to command it to UPS Mode or High Efficiency Mode.
- UPS Controller BMS Interface – the UPS Controller is able to communicate with a building management system or other external control equipment, and receive a remote mode control command. Refer to specific instructions provided by the building management system integrator.

The Hybrid UPS systems will then remain in the desired mode until commanded otherwise, or until a loss of utility voltage forces the system into Emergency Mode. Note that the UPS Controller will typically be integrated with a building management system or other external control system for automatically switching between modes and adjusting power demand levels. If utility power is lost, forcing the Hybrid UPS systems into Emergency Mode, the commanded mode will be retained in memory and the system will attempt to return to that mode when utility power is restored.

Taking a Hybrid UPS Unit out of Service

CAUTION	Taking a unit out of service will reduce the capability of the entire Hybrid UPS system which may cause an overload condition that results in loss of all power to the critical loads. Make sure there is sufficient capacity from the remaining Hybrid UPS units to supply the critical load before taking a unit out of service.

A single Hybrid UPS system can be isolated from the rest of the MultiPac for maintenance or for any other reason. This can be done in several ways:

- UPS Controller Touch Screen Display – If the touch screen display panel is dark, touch it anywhere to activate it. When the screen becomes active, enter the Maintenance screen using password, and press the MultiPac Disable button for the desired Hybrid UPS unit.
- UPS Controller BMS Interface – the UPS Controller is able to communicate with a building management system or other external control equipment, and receive a remote command to disable a Hybrid UPS unit. Refer to specific instructions provided by the building management system integrator.

Operating an Individual Hybrid UPS System

CAUTION	Operating an individual Hybrid UPS unit in parallel with the outputs of other Hybrid UPS systems in a MultiPac will result in load fault conditions that may automatically shut down some or all Hybrid UPS systems and drop the critical load. Securely isolate the output of an individual Hybrid UPS unit before attempting to operate it.

An individual Hybrid UPS unit can be operated independently of the rest of a MultiPac for service reasons. However care must be taken to avoid impacting proper operating of the remaining MultiPac system. This requires that temporary control connections be made at the Grid Interlock and Stand Alone Interlock terminals in the JUCB, and should only be done by an Authorized Service Provider. Since output of the individual Hybrid UPS unit will no longer be synchronized with the rest of the Hybrid UPS system MultiPac, its load output connections must also be isolated from the rest of the Hybrid UPS systems' outputs.

NOTE	Operating an individual Hybrid UPS unit that is not enabled as part of the MultiPac should only be done with the assistance of a Capstone Authorized Service Provider.

Returning a Hybrid UPS Unit to Service

Once a Hybrid UPS system has been taken out of service by disabling it from the MultiPac, it can be restored to service by simply re-enabling it. This can be done in several ways:

- UPS Controller Touch Screen Display – If the touch screen display panel is dark, touch it anywhere to activate it. When the screen becomes active, enter the Maintenance screen using password, and press the MultiPac Enable button for the desired Hybrid UPS unit.
- UPS Controller BMS Interface – the UPS Controller is able to communicate with a building management system or other external control equipment, and receive a remote command to enable a Hybrid UPS unit. Refer to specific instructions provided by the building management system integrator.

Once the individual Hybrid UPS system has been re-enabled as part of the MultiPac, it will start acknowledging commands from the UPS Controller and will synchronize its output to fit the desired operating mode. Utility Input and Load Output power connections will be made automatically, and loads will then be shared between all available Hybrid UPS systems.

NOTE	Make sure any power connections that were isolated for service reasons have been reestablished to make power available to the critical loads, utility grid connections, and external energy storage system.

Transfer to/from Utility Power

If the Hybrid UPS system is operating in UPS Mode or High Efficiency Mode, it will attempt to maintain synchronism of the load output to the utility input voltage in both frequency as well as phase relationship. Therefore, during normal operation it is possible to seamlessly transfer the critical load from the output of the Hybrid UPS systems to the utility source, or vice versa, using a closed transition scheme. Automatic Transfer Switches (ATS) are available with the ability to make a momentary closed transition when voltages and phase relationship of the two sources are within preset limits. Neither the Hybrid UPS systems nor the UPS Controller have direct control over this transfer, and do not need to control the ATS for proper system operation. The UPS Controller will accept input signals from an external transfer scheme in order for its local display to provide an overview of the state of the system. Refer to instruction provided by the building management system integrator or equipment installer for how to activate the transfer scheme.

Transfer from Hybrid UPS to Utility Power

When a transfer scheme moves the critical load from the output of the Hybrid UPS systems to the utility source, the Hybrid UPS systems will see a load drop, but will continue to supply voltage to their load outputs, regardless of whether they are operating in UPS Mode or High Efficiency Mode. If the system was in the High Efficiency Mode, all power from the turbine generators will be delivered to the utility power connection. If this transfer to utility power is only intended to be temporary, the Hybrid UPS systems can be left in the desired operating mode where they will remain ready for retransfer of the critical loads. If the transfer was for service or other reasons, the system can be shut down as described below.

Transfer from Utility Power to Hybrid UPS

Once a Hybrid UPS system is started and operating in either UPS Mode or High Efficiency Mode, it is able to accept a block transfer of loads that were previously powered by the utility source. Since there will be no inrush currents associated with motor starting or transformer magnetization during a closed transition transfer, the Hybrid UPS systems will simply see a step load change within their steady state power capability. This may result in a brief voltage drop at the output of the Hybrid UPS system, however a properly designed installation should maintain sufficient power quality to meet the requirements of the critical load.

System Shut-down

The Hybrid UPS system is designed for continuous operation, and will not be shut down in normal operation. There are several means to shut the system down, depending on the urgency of removing power from the critical loads.

Normal Shutdown

A normal shutdown would typically be done after the critical loads have been transferred to the utility power source (as described above), or the loads themselves have been shut down for service reasons. A normal shutdown process will transition the system from either of its' operating modes (UPS Mode or High Efficiency Mode), to the Standby Mode. During this transition, power will be removed from the critical load and, if the turbine generators are running, the system will make sure the external batteries are properly charged before stopping the turbines using a cooldown. The power connection to the utility will then be disconnected. While power will be quickly disconnected from the load, the completion of a normal shutdown can take many minutes, depending on the state of charge of the energy storage system. A normal shutdown can be initiated from the UPS Controller in two ways.

- UPS Controller Touch Screen Display – If the touch screen display panel is dark, touch it anywhere to activate it. Enter the Maintenance screen using password, and press the Local/Standby button. This will put all units into the Standby Mode.
- UPS Controller BMS Interface – the UPS Controller is able to communicate with a building management system or other external control equipment, and receive a remote stop command. Refer to specific instructions provided by the building management system integrator.

Fast Stop

A Fast Stop function is available through a discrete input to the UPS Controller. When activated, the Fast Stop will immediately disconnect power to the load, and force any running turbine generators into a cooldown without regard to battery state of charge. The power connection to the utility will be disconnected as soon as the turbines have completed their cooldown, leaving the system in the Standby Mode. Fast Stop is the recommended system stop function for quickly removing load power, as it is not as damaging to the turbines as the E-Stop function described below.

The Fast Stop discrete input can be wired to a building management system for automatic operating in case of emergency, or can be wired to a manual "System Stop" button. Refer to specific instructions provided by the building management system integrator or system installer for the location of any System Stop button or instructions how to activate this function from the building management system.

Emergency Stop

WARNING	Activation of the Emergency Stop function represents an extremely abnormal event which could be due to building, equipment, or personnel safety concerns. Thoroughly investigate the reason for issuing an Emergency Stop command and make sure the cause has been remedied before attempting to return the system to normal operation.

CAUTION	Repeated use of the optional Emergency Stop function will result in damage to the MicroTurbine. Use only in emergency situations.

All Capstone MicroTurbines have an emergency stop function called "E-Stop", which will immediately disconnect power from the load as well as the incoming utility, shut off fuel input, and force the turbines into a warmdown. In a warmdown, the turbines do not receive power from the utility or the external energy storage system, and therefore cannot be motored to a controlled stop. Instead, the turbines coast to a stop and excess thermal energy stored in the engine's recuperator section is released through a compressor bypass valve. This uncontrolled stop puts abnormal mechanical and thermal stresses on the system, and can reduce the turbine generator life. Therefore, E-Stop should only be used as a worst case emergency means to shut the system off.

The E-Stop function is not available as a discrete relay input to the UPS Controller, but may be directly wired to a building management system for automatic operation in case of emergency, or may be wired to a manual "Emergency Stop" button. Refer to specific instructions provided by the building management system integrator or system installer for the location of any Emergency Stop button or instructions how to activate this function from the building management system.

After an emergency stop, the power to the MT must be turned off for 30 seconds before a restart can be attempted. Emergency stops should **NEVER** be used for routine shutdowns. Also, after an E-Stop, you may want to manually close the external fuel isolation valves to shut off potential fuel flow into the MT in case there is a fuel leak. The external fuel isolation valve must be returned to the open position before a restart of the MT is attempted. An E-Stop operation should be viewed as an extremely abnormal event, and a thorough investigation as to why the E-Stop command was given should be conducted before returning the system to normal operation.

Operation Under Fault Conditions

The Hybrid UPS system has been designed to provide high availability of power output even when a utility source is unavailable, and even if the turbine generator itself cannot operate for some period of time. A well designed installation will also include n+1 or better redundancy such that no single unit failure will compromise power to the critical loads. However, there are a variety of fault conditions that can potentially disrupt power to the critical load. The UPS Controller continuously monitors the status of the Hybrid UPS systems in its MultiPac, and provides two hardwired discrete alarm outputs as well as updated fault registers that can be read using Modbus TCP/IP. A building management system or other external control system can use this information to take appropriate actions that may mitigate loss of power to the critical load. Refer to specific instructions provided by the building management system integrator or system installer for what external actions will be taken and any manual intervention required with the UPS Controller or Hybrid UPS systems.

Orderly Shutdown Alarm

CAUTION	The Orderly Shutdown alarm does not guarantee that the Hybrid UPS system will continue producing power for any specific period of time in order to avoid potential business losses or damage to critical load equipment. Assure that the external actions taken in the presence of this alarm are appropriate to the potential loss of power to the critical loads.

Data center and telecommunications equipment can be shut down in an orderly manner that preserves information and/or transfers operation to other equipment. Typically this requires several minutes to complete. To help mitigate loss of data or missed opportunity to transfer operation to another piece of equipment, the UPS Controller can issue an Orderly Shutdown alarm that signals conditions that may result in power system shutdown in five minutes. For example, this Orderly Shutdown alarm may be signaled whenever:

- Battery State of Charge is less than Five Minutes – even if the Hybrid UPS system is operating in UPS Mode or High Efficiency Mode, insufficient external energy storage could result in the critical loads being dropped should a utility fault occur. Note that the actions taken as a result of such an alarm may be different, depending on whether the turbine generators are running or not, and whether the utility source is present or not.

Refer to the UPS Controller User Manual (400028) for a description of how your system is set up.

Imminent Shutdown Alarm

CAUTION	The Imminent Shutdown alarm does not guarantee that the Hybrid UPS system will continue producing power for any specific period of time in order to avoid potential business losses or damage to critical load equipment. Assure that the external actions taken in the presence of this alarm are done quickly to mitigate loss of power to the critical loads.

There may be sufficient notice of potential loss of load power output for the UPS Controller to issue an Imminent Shutdown alarm. Typical external action taken in response to this alarm would be automatic transfer of critical loads to the utility source, if it is available. For example, this Imminent Shutdown alarm may be signaled whenever:

- Load Output is Severely Overloaded – if the system is in Emergency Mode and goes into a severe overload condition, there may be only seconds of time before the integral protective functions of the Hybrid UPS systems declare a fault and stop load output power flow.
- Inverter Reserve is Lost – if some Hybrid UPS units are taken out of service for any reason and/or there is a moderate overload condition on the critical load output, the UPS Controller will signal this loss of capacity. The inverter reserve can be preset to represent one or more Hybrid UPS system's output capability. In this case, the external actions taken may include non-critical load shedding or switching critical loads to an alternate source temporarily.

Refer to the UPS Controller User Manual (400028) for a description of how your system is set up.

Fault Data Registers

The UPS Controller monitors the fault condition of each Hybrid UPS system it is connected to, and periodically writes this fault status into multiple data registers that can be read externally using Modbus TCP/IP. Some of this fault data is used within the UPS Controller to drive the specific alarms noted above. Other fault data may be less critical to continued operation, but should be recognized by facility personnel who can take appropriate action. For example, the external building management system may be set up to poll selected fault registers and signal users of certain conditions, such as:

- External Battery Power is Unavailable – if the system is experiencing extremely low battery state of charge or there is a fault on the battery bus, then the Hybrid UPS system can no longer guarantee power output would be available in case the utility becomes unavailable. This is not an Imminent Shutdown alarm in the sense that it should drive automatic transfer of power to the utility source, since the Hybrid UPS system is still able to deliver utility power to the load. However it should direct facility personnel to correct the problem immediately, and could also be a reason to command the Hybrid UPS systems into High Efficiency Mode so at least there would be turbine power available in case of a utility outage.
- Fuel Source is Unavailable – if a loss of fuel pressure fault is present, it means that turbine power will not be available to supplement the external battery in the case of an extended outage. This is neither an Imminent Alarm nor an Orderly Shutdown alarm, but facility personnel should be alerted to correct the problem so the system will be capable of supporting an extended utility outage.

A list of the available fault registers is provided in the UPS Controller Technical Reference (410081).

Using the UPS Controller

The Capstone UPS Controller is required for any application with more than one Hybrid UPS microturbine. The Capstone UPS Controller accessory acts as a master for up to ten Hybrid UPS microturbines, and coordinates MultiPac operation to provide high availability of power to the critical load.

The UPS Controller can:

- Display overall system status as well as details for individual microturbines.
- Start and Stop the system and change the desired operating modes.
- Communicate with a Building Management System to share monitored microturbine data, accept power demand and other control commands, and signal potential shutdown conditions.
- Coordinate Hybrid UPS microturbine state transitions, including consideration of external battery state of charge information.
- Provide a common communications connection for a PC with CRMS software.

Figure 4 shows the typical connections available from the UPS Controller. Refer to the UPS Controller User Manual (400028) for a complete description of this accessory and how to operate it.

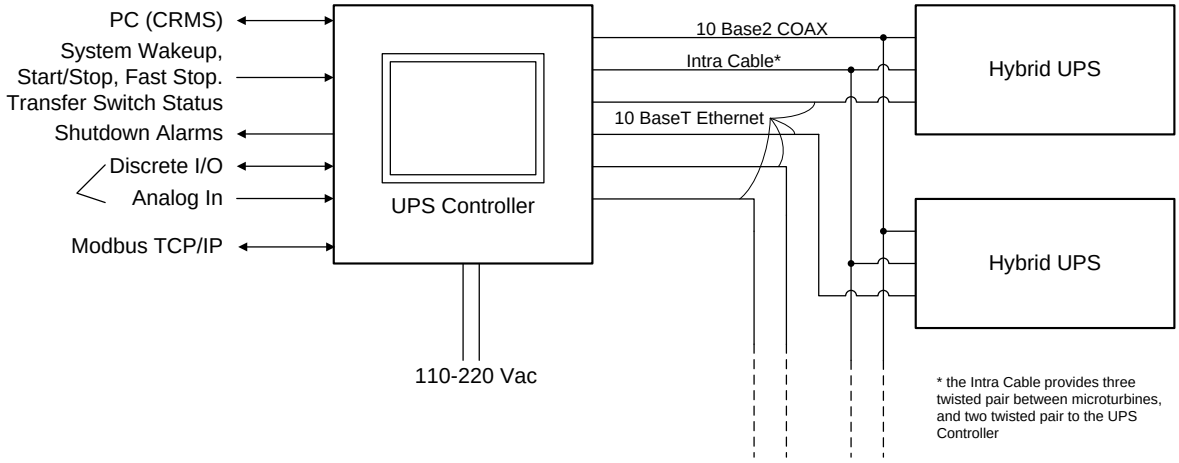


Figure 4. UPS Controller External Connections

Using the Display Panel

Use of the Display Panel (Figure 5) is described in the following paragraphs.

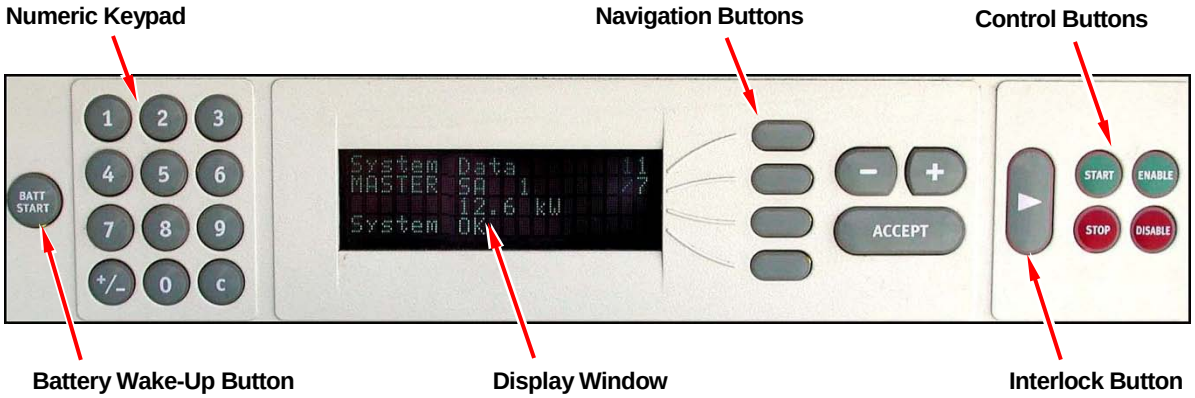


Figure 5. Display Panel and Functions

CAUTION	Attempting to operate a single Hybrid UPS system while it is connected to the output of other operating Hybrid UPS systems may cause all systems to sense a fault condition and stop providing power to the critical load. Only attempt to operate an individual system if it is isolated from all other Hybrid UPS system outputs.

The Display Panel is located on the front of the package above the engine air inlet, and is used to control a selected few operating functions, show individual system status, and access data stored within the microturbine system. The Display Panel includes a keypad, a display window, navigation buttons, and system control buttons. The paragraphs below describe Display Panel operation.

The primary control and configuration interfaces to the Hybrid UPS system are the UPS Controller and the Capstone Remote Monitoring System (CRMS) software. During normal operation, the UPS Controller is the MultiPac master for all Hybrid UPS systems connected to it. In this operating mode, all Hybrid UPS systems are MultiPac enabled and the control functions of the local Display Panel are limited. When a Hybrid UPS microturbine is MultiPac disabled, the local Display Panel functionality is somewhat increased. However, proper operation of the Hybrid UPS microturbine is restricted to operation when it is isolated from the outputs of all other Hybrid UPS systems and the Grid Connect and Stand Alone Interlock connections are correctly activated.

Display Panel Areas

The **BATT START** button, at the far left of the Display Panel, is used to wake a Hybrid UPS system from sleep mode.

The **Numeric Keypad**, located to the left of the Display Window, is for data input. The system accepts data input only on specific screens, and the input line must be selected, indicated by the flashing line. Data input from the Numeric Keypad requires logging-on with a password (refer to Logging On with a Password on page 37).

The **Display Window** is in the center of the Display Panel. The Display Window can display four lines of twenty characters, each of which indicate menu hierarchy position, data display, and data input.

The **Navigation Buttons** are located to the right of the Display Window, and consist of four buttons arranged vertically, each with a line to its left indicating a line of data in the Display Window. These four buttons, plus the buttons just to their right labeled (**-**), (**+**), and ACCEPT, are the navigation buttons; they are used for selecting various display screens or data items.

Menu Navigation

Movement around the top-level menu screens can be accomplished by use of the Navigation Buttons. The top line of the display always shows the name of the current top-level menu. Refer to Figure 6 for panel and display layout.

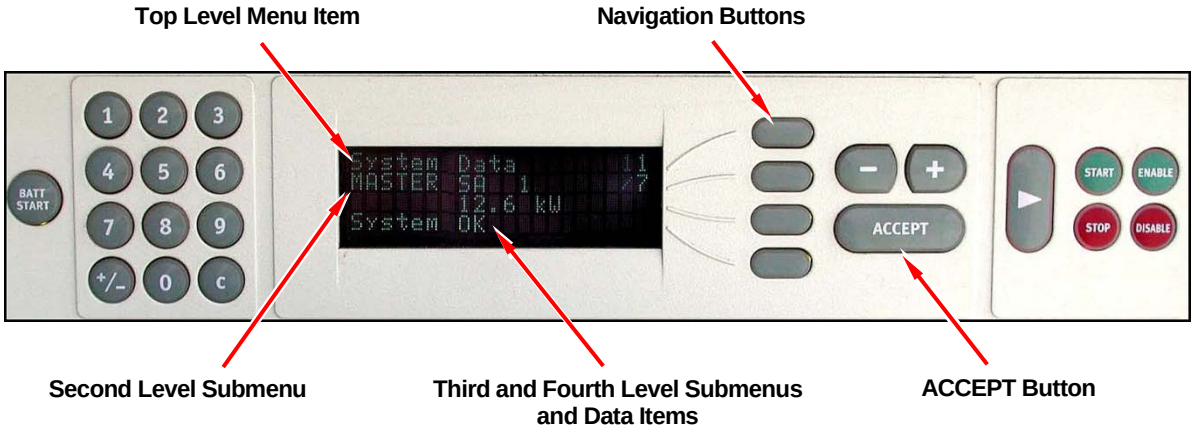


Figure 6. Display Panel and Navigation Functions

To move around the top-level menus, press the topmost of the four line Navigation Buttons. The menu position indicator numbers at the right end of the top line will flash. When the numbers are flashing, press the (**-**) or (**+**) buttons to move around the menus.

Each of the top-level menu screens has a number of submenus. The second line in the Display Window shows the current submenu. Movement around the submenus is similar to the top-level menus except you must press the second line Navigation Button to select line two of the display. When the numbers are flashing, press the (**-**) or (**+**) buttons to move around the submenus.

When you reach the desired menu, press the ACCEPT button to choose the menu, or wait 20 seconds for the system to automatically accept the menu selected.

The third and fourth levels display the selected performance data or allow input, like passwords or adjustment of power settings. The descriptions of each screen or submenu are grouped according to the top-level menu.

Display Panel Data Entry

Data input requires selection of the appropriate level with the Navigation Buttons, causing the display line to flash. Enter data using the Numeric Keypad, or scroll through available data entry options with the (**-**) or (**+**) buttons and press the ACCEPT button when finished. To make changes to any system set-up or operational mode requires the entry of a user password. Numeric entries can be cancelled by use of the (**-**) button.

Logging On with a Password

To enter commands from some of the Display Panel menus, the user must log on with a valid password (the description of the various menus on the following pages includes whether logging on with a password is required).

NOTE	The default user password (at the Display Panel) is set to **87712370**. In the event of a lost user password, your Capstone Authorized Service Provider can reset the user password to this default.

To log on with a password, follow these steps:

1. At the top-level System Data Menu, push the second level Navigation Button and the (**-**) or (**+**) buttons until you come to the Enter Password submenu.
2. Select the third level Navigation Button (the display indicates "**********"). Enter the current password (see the above notes).
   - Note that the display of ********** becomes **--------** as you enter the password.
3. Press the ACCEPT Button. The display will indicate "PROTECTED LEVEL SET".
4. You are now logged into the system.

Not all data items can be modified at the user password level.

Changing the Password

The user password can be changed at any time using the following steps.

NOTE	The user must be logged-in (with a password) to change the password.

1. Go to the top-level System Data menu, push the second level Navigation Button and the (**-**) or (**+**) buttons until you come to the User Password submenu.
2. Select third level Navigation Button (the display indicates ********Change). Enter the new password.
3. Press the ACCEPT button. A confirmation message will be posted that states the password needs to be verified.
4. Press the fourth level Navigation Button. Verify the Password on the fourth level (the display indicates ********Verify). Re-enter the "new" password to verify.
5. Press the ACCEPT button. A confirmation message will be displayed that states the password has been verified. If the new password is not verified in this manner, the old password will remain in effect.

Display Panel Menus - Overview

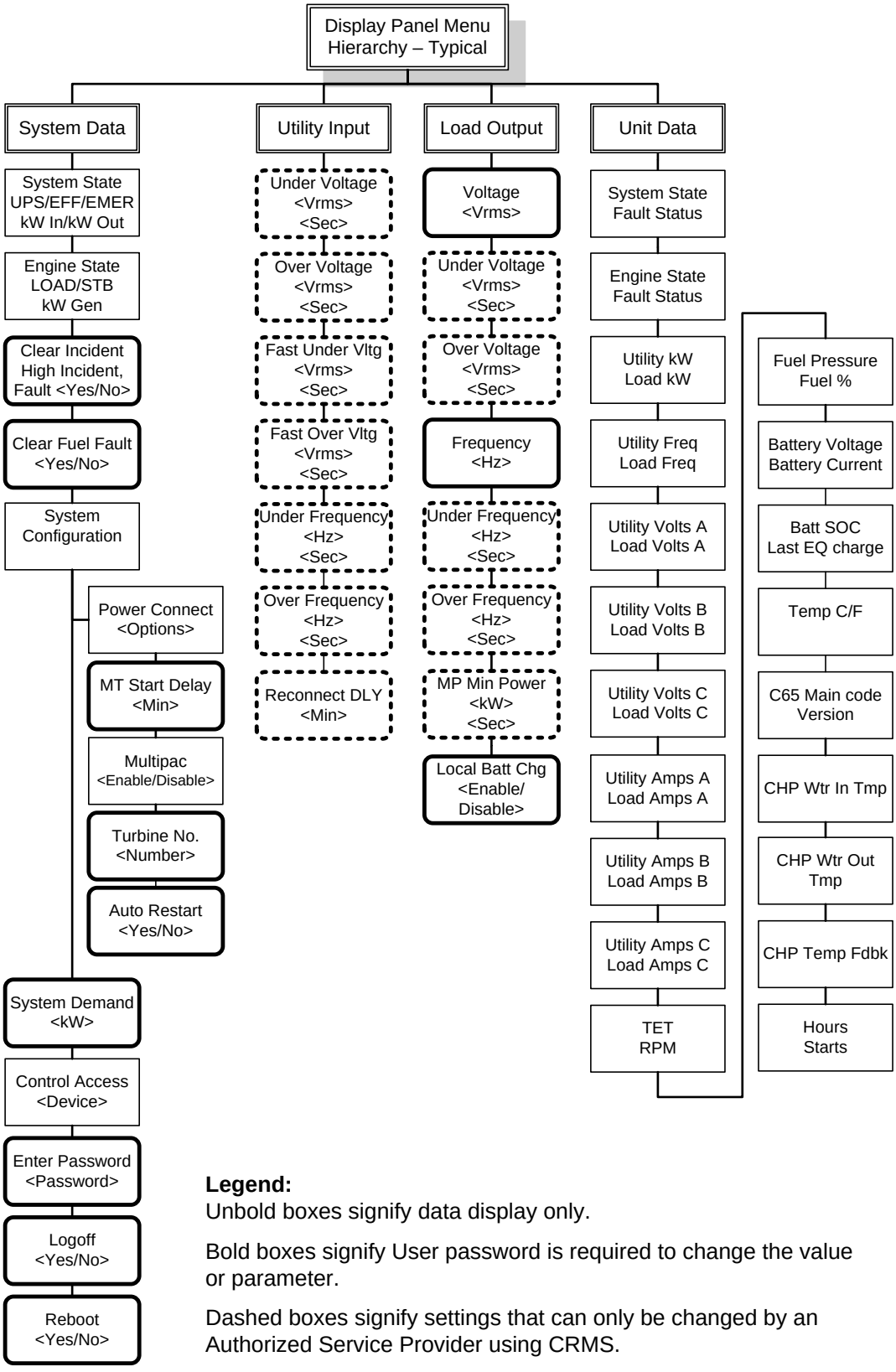
The Display Panel menu hierarchy shown in Figure 7 presents the typical structure of the system software menus and submenus for the Model C65 Hybrid UPS MicroTurbine with. These menus and submenus are also detailed in text following the menu hierarchy chart.

System Data Menu

NOTE	The user is able to view the data on various screens of the System Data Menu without logging on. Some of the settings require logging on with a user password.

On power-up, the Display Panel defaults to the top-level System Data menu. System Data submenus are detailed below with a sample of the actual display for each submenu. The same applies for the other top level menus, as applicable.

NOTE	The user is able to view the data on various screens of the System Data Menu without logging on. Some of the settings require logging on with a user password.



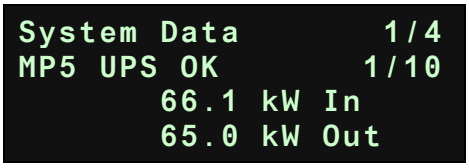
Legend:
Unbold boxes signify data display only.

Bold boxes signify User password is required to change the value or parameter.

Dashed boxes signify settings that can only be changed by an Authorized Service Provider using CRMS.

Figure 7. Display Panel Menu Reflecting Function Hierarchy

System Output Submenu



The second line shows whether it is a Single (SNGL) unit or a MultiPac (MP) unit, the MicroTurbine number, the current system state, and the system fault status as OK or FLT. This submenu also gives the input power from the Utility grid source as "kW In" on the third line and the total output of the system in kilowatts "kW Out" on the fourth line. Note that if the turbine is generating more power than required by the load, the kW In will be negative. A negative value for kW In indicates net export from the Hybrid UPS system to the grid connection point for use by other loads in the facility, and does not necessarily mean export of power to the external utility grid.

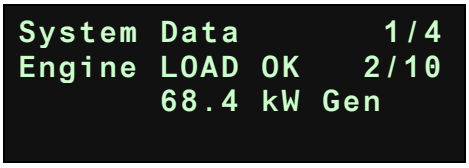
The system state messages are abbreviations of the actual system states, as summarized in Table 4. Only three system state messages match the desired operating modes of Standby (STB), UPS Normal Mode (UPS), and High Efficiency Mode (EFF). The remaining messages represent transition states that should not persist in a fully functioning system.

Note that all Hybrid UPS systems in a MultiPac must be commanded to the same operating mode; that is ether Standby, UPS Normal, or High Efficiency. However, when the UPS Controller is dispatching individual Hybrid UPS units using its High Efficiency control logic, the displayed system state will be UPS for units that have not had their engines enabled to start, and EFF for units that have received an engine start command.

Table 4. Hybrid UPS System State Messages and Description

Hybrid UPS System State	Microturbine Display	Description
STAND BY	STB	System is out of service
POWER UP	PWUP	System is in power-up state
BATT RECHARGE	BATR	Engine recharging external batteries
BATT ENABLE	BATE	System is ready to output power to critical load from external batteries
UTILITY ENABLE	UTEN	System is ready to output power to critical load from utility source
UPS NORMAL	UPS	System operating in normal UPS mode
HIGH EFFICIENCY	EFF	System operating in high efficiency mode
LOAD RECOVERY	LRCV	System recovering from load fault
EMERGENCY	EMER	System is providing power to critical loads in absence of utility source
SW DOWNLOAD	SWLD	System is downloading software
SHUTDOWN	SDWN	System is waiting for correct engine state to allow transition to standby state

Turbine Output Submenu



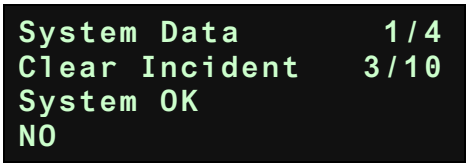
The second line shows the engine generator state, and whether the engine is OK or in a fault condition (FLT). This submenu also gives individual generator output as "kW Gen" on the third line. Note that in High Efficiency Mode, engine generator power that is greater than what is required to support the load output will be export to the Grid LCM and/or supplied to the DC bus.

The engine state messages are abbreviations of the actual engine states, as summarized in Table 5.

Table 5. Hybrid UPS Engine State Messages and Description

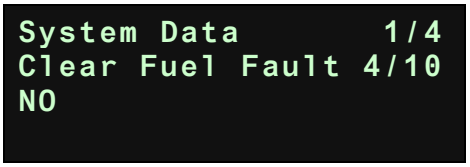
Hybrid UPS Engine State	Microturbine Display	Description
STAND BY	STB	Engine ready to start
LIFT OFF	LIFT	Engine rotation started
LIGHT OFF	LITE	Engine ignition started
ACCEL	ACEL	Engine accelerating to idle
LOAD	LOAD	Engine ready to output power to load
COOLDOWN	CDWN	Stop command issued and engine in cool down state
WARMDOWN	WDWN	Stop command issued and engine in warm down state
RELIGHT	RLIT	Engine commanded to light off again before rotation stops
SETDOWN	SETD	Engine rotation stopped
SHUTDOWN	SDWN	Engine is shutdown and transitioning to standby state

Clear Incident Submenu



The Clear Incident submenu attempts to clear the highest-level fault and to return the system to standby. The <High Incident, Fault> line displays the system highest fault type and the associated identification number of the fault currently reported by the system. If the fault can be cleared, the fault # line will be updated with the next highest active fault, or System OK if all faults were cleared. If the same fault remains, the fault cannot be cleared. Note that the user must be logged in with the current password to clear the faults.

Clear Fuel Fault Submenu



The Clear Fuel Fault clears a fault originated by the fuel vent system which causes a MT shutdown. The user must bring the MT back up (power up), then activate the 'Clear Fuel Fault' which clears the fault. Then the user must do a Reboot. The cause of this fault may be a leak in the system, so troubleshooting and leak detection must be done immediately. Note that the user must be logged in with the current password to clear the faults.

System Configuration Submenu

The System Configuration submenu contains system settings and allows the user to adjust the third level data, as detailed below:

Power Connect Submenu

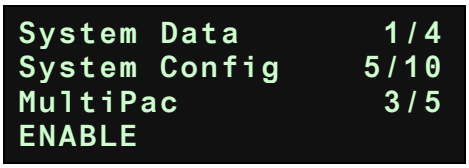
The Power Connect submenu allows the user to view the desired operating mode of the Hybrid UPS system.

- Standby
- UPS Mode
- High Efficiency Mode

Microturbine Start Delay Timer

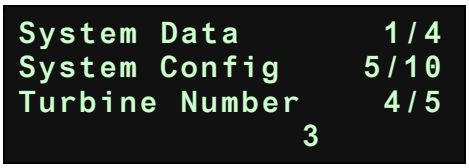
The microturbine start delay timer submenu allows the user to set a delay timer that determines how long a non-operating turbine will wait before entering a start sequence when utility power becomes unavailable. The setting is adjustable from 0 to 10.0 minutes. The initial factory setting is 1.0 minute. Note that the user must be logged in with the current password to change this setting.

MultiPac Submenu



The MultiPac submenu shows the user whether a MicroTurbine is enabled in the MultiPac or not.

Turbine Number Submenu



The main controller MicroTurbine in a MultiPac system is designated as the "Master", and must be assigned as number "1". Other MicroTurbines may be assigned in any order in a MultiPac system, however, each MT must have a unique turbine number. Note that the user must be logged in with the current password to change the turbine number.

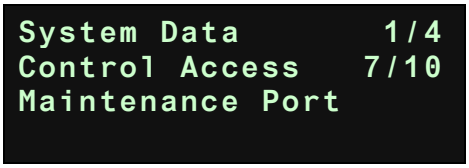
Auto Restart Submenu

The Auto Restart submenu enables or disables the system's ability to automatically attempt to restart the turbine after an incident driven shutdown. Note that the user must be logged in with the current password to change this setting. The normal setting for a Hybrid UPS system is YES.

System Demand Submenu

The System Demand submenu allows the user to view, and in certain cases set the Power Demand in kW when it is operating in High Efficiency Mode. Normally the System Power Demand value will be determined by the UPS Controller, and will be displayed on this submenu. Note that to change this value from the Display Panel, the Hybrid UPS system must be MultiPac disabled and the user must be logged in with the current password.

Control Access Submenu



The Control Access submenu displays which communication device currently has control authority for changing settings of the MicroTurbine.

- Display Panel
- User Port
- Maintenance Port

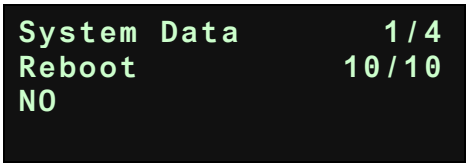
Enter Password Submenu

The Enter Password submenu allows the user to logon and access the MicroTurbine controls. The factory default User-level password is 87712370. Refer to the previous section on passwords for more details on entering and changing passwords.

Logoff Submenu

The Logoff submenu allows the user to logoff and prevents further access to the MicroTurbine controls. Note that the system will automatically logoff if there is no user interaction with the Display Panel for more than four minutes.

Reboot Submenu



The Reboot submenu allows the user to reboot the system.

If YES is selected, the system will reboot immediately. Note that the user must be logged in with the current password to reboot the system.

Utility Input Connection Menu

The top-level Utility Input connection menu establishes operation parameters in the Grid Load Control Module (GLCM). These are primarily the UL 1741 (IEEE 1547) Utility Grid Connect Protective Relay functions, and their setpoints are displayed here.

Refer to the following reference documents as required:

- Protective Relay Functions (410033)

The Utility Input submenus are detailed below:

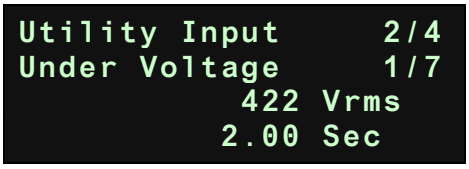
NOTE	In the following submenus, the first line always displays the Grid Connect top level menu.

WARNING	Do not attempt to change any Grid Connect Protective Relay functions. Injury to personnel and/or damage to equipment can occur. Contact your Capstone Authorized Service Provider for additional information.

NOTE	The primary Grid Connect Protective Relay function is to ensure that the MicroTurbine does not energize utility wires de-energized by the utility.

NOTE	All of the following Protective Relay settings can only be changed by an Authorized Service Provider using CRMS.

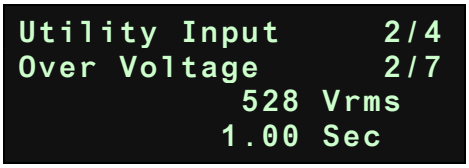
Under Voltage Submenu



The Under Voltage submenu shows the line-to-line voltage and associated delay time. If the RMS voltage between any phases falls below this setting, the delay timer is started. If the voltage has not recovered at the end of this time, the system will enter Emergency Mode. This is adjustable from 352 up to the Over Voltage setpoint in 1 volt increments. Initial Factory Setting is 422 VAC line-to-line.

Under Voltage Delay establishes the time allowed for any phase voltage to fall below the Under Voltage limit. The delay is adjustable from 0.01 up to 10 seconds in 0.01 second increments. Initial Factory Setting is 2.0 seconds.

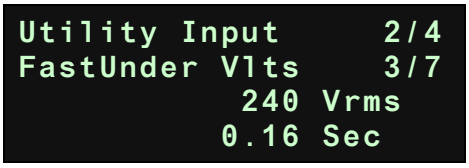
Over Voltage Submenu



Over Voltage submenu shows the line-to-line voltage and associated delay time. If the RMS voltage between any phases rises above this setting the delay timer is started. If the voltage has not subsided by the end of this time, the system will enter Emergency Mode. This is adjustable from 528 down to the Under Voltage setpoint in 1 volt increments. Initial Factory Setting is 528 Volts.

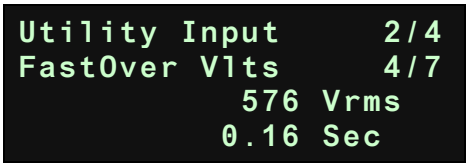
Over Voltage Delay establishes the time allowed for any phase voltage to rise above the Over Voltage limit. The delay is adjustable from 0.01 to 10 seconds in 0.01 second increments. Initial Factory Setting is 1.0 second.

Fast Under Voltage Submenu



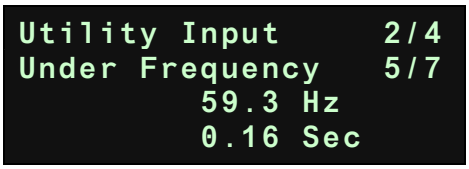
Fast Under Voltage submenu shows the line-to-line voltage and associated delay time. The system will cease power import from or export to the grid within 1 msec if any phase RMS voltage drops below the Fast Under Voltage setting for the set time delay. If the grid voltage re-stabilizes within 1 second of the initial under voltage, then the system will resume its power connection to the grid; otherwise, the system will enter Emergency Mode. The Fast Under Voltage at which this sequence will be triggered is adjustable from 0 VAC up to the Under Voltage setpoint. The delay time is adjustable from .03 to 1.00 second in .01 second increments. Initial Factory Settings are 240 V line-to-line and .16 second delay.

Fast Over Voltage Submenu



Fast Over Voltage submenu shows the line-to-line voltage and associated delay time. The system will cease power import from or export to the grid within 1 msec if any phase RMS voltage exceeds the Fast Over Volts setting for the set time delay. If the grid voltage re-stabilizes within 1 second of the initial over voltage, then the system will resume its grid power connection; otherwise, the system will enter Emergency Mode. The Fast Over Voltage at which this sequence will be triggered is adjustable here from the Over Voltage up to 634 volts. The delay time is adjustable from .03 to 1.00 second in .01 second increments. Initial Factory Settings are 576 V line-to-line and .16 second delay.

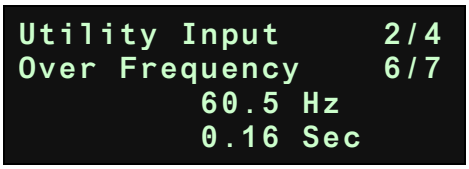
Under Frequency Submenu



Under Frequency submenu shows the system under frequency and associated delay time. If the grid frequency falls below this under frequency setpoint for the set delay time, the system will enter Emergency Mode. The frequency is adjustable from 45 Hz up to the Over Frequency setting, in 0.1 Hz increments. Initial Factory Setting is 59.3 Hz.

The Under Frequency Delay is the number of seconds allowed for the Under Frequency condition before the system enters Emergency Mode. This is adjustable from 0.01 to 10 seconds in 0.01 second increments. Initial Factory Setting is .16 second.

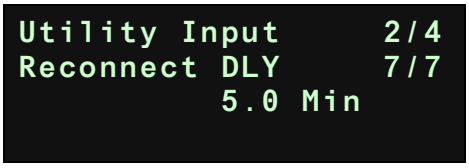
Over Frequency Submenu



Over Frequency submenu shows the system over frequency and associated delay time. If the grid frequency exceeds this over frequency setpoint for the set delay time, the system will enter Emergency Mode. The frequency is adjustable from the Under Frequency setting to 65, in 0.1 Hz increments. Initial Factory Setting is 60.5 Hz.

The Over Frequency Delay is the number of seconds allowed for the Over Frequency condition before the system shuts down. This is adjustable from 0 to 10 in 0.01 second increments. Initial Factory Setting is 0.16 second.

Reconnect Delay Submenu



Reconnect Delay submenu defines the time that a Hybrid UPS system will continue generating power in Emergency Mode before reconnecting to the utility grid. The turbine checks that the utility grid voltage is within the protective relay settings for this time limit before reconnecting to the grid. It is the minimum amount of time the system will operate in Emergency Mode when the turbine is producing power. Initial Factory Setting is 5 minutes. The timer can be set from 5 to 30 minutes.

Load Output Connection Menu

The top-level Load Output connection menu establishes voltage and frequency output from the Hybrid UPS microturbine in the Load LCM (LLCM), and is essentially the same as for a normal microturbine operating in Stand Alone mode. It also establishes the operational limits for voltage and frequency. These limits are usually set when the MicroTurbine is commissioned and are not changed once set.

The Load Output submenus are detailed below:

NOTE	In the following submenus, the first line always displays the Stand Alone top level menu.

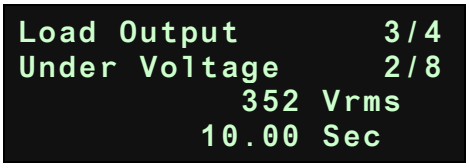
Voltage Submenu

Voltage submenu is used to view and set the nominal RMS output voltage (line-to-line) to the critical load. Voltage is adjustable from 150 to 480 in one-volt increments. Initial Factory Setting is 480 VAC line-to-line. The UPS Controller will set this voltage for all Hybrid UPS systems operating in a MultiPac, and the user cannot change this value from this Display Panel when the system is MultiPac enabled. Note that to change this value from the Display Panel, the Hybrid UPS system must be MultiPac disabled and the user must be logged in with the current password.

WARNING	Do not attempt to change any Stand Alone Protective Relay functions. Injury to personnel and/or damage to equipment can occur. Contact your Capstone Authorized Service Provider for additional information.

NOTE	All of the following Protective Relay settings can only be changed by an Authorized Service Provider using CRMS.

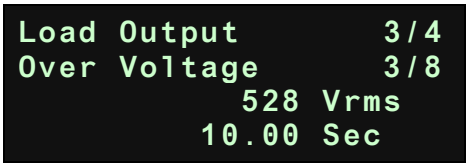
Under Voltage Submenu



Under Voltage submenu shows the line-to-line voltage and associated delay time. If the RMS voltage between any phases falls below this setting, the delay timer is started. If the voltage has not recovered at the end of this delay time, the system will shut down. Voltage is adjustable from 0 up to nominal. Initial Factory Setting is 352 volts.

The Under Voltage Delay establishes the time period allowed for any phase voltage to fall below the Under Voltage limit. The delay is adjustable from 0.01 up to 10 seconds in 0.01 second increments. Initial Factory Setting is 10 seconds.

Over Voltage Submenu

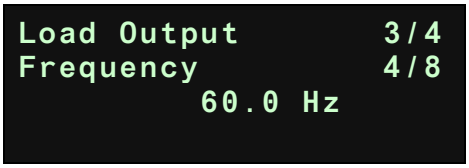


Over Voltage submenu shows the line-to-line voltage and associated delay time.

If the RMS voltage between any phases rises above this setting the delay timer is started. If the voltage has not subsided by the end of this time span, the system will shut down. Voltage is adjustable from 528 down to nominal in 1 volt increments. Initial Factory Setting is 528 Volts.

Over Voltage Delay establishes the time span allowed for any phase voltage to rise above the Over Voltage limit. The delay is adjustable from 0.01 to 10 seconds in 0.01 second increments. Initial Factory Setting is 10 seconds.

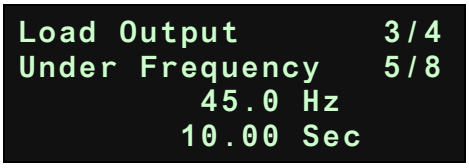
Frequency Submenu



Frequency submenu establishes the nominal output frequency. This is adjustable from 45 to 65 in 1-Hz increments. Initial Factory Setting is 60 Hz. When operating in UPS Mode or High Efficiency Mode, output frequency will automatically be adjusted to maintain synchronism with input power from the Utility grid. This frequency setting, therefore, only takes precedence when the system is operating in Emergency Mode.

The UPS Controller will set this frequency for all Hybrid UPS systems operating in a MultiPac, and the user cannot change this value from this Display Panel when the system is MultiPac enabled. Note that to change this value from the Display Panel, the Hybrid UPS system must be MultiPac disabled and the user must be logged in with the current password.

Under Frequency Submenu



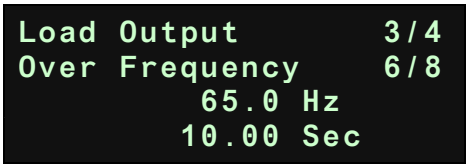
CAUTION	Adjusting the Load Output under frequency setting above the Utility Input under frequency setting may result in the Hybrid UPS system disconnecting power from the critical load when the Utility grid frequency drops. Only adjust the Load Output under frequency to a value less than the Utility Input under frequency setting.

Under Frequency submenu shows the system under frequency and associated delay time. If the output frequency falls below this under frequency setpoint for the set delay time, the system will shut down. The frequency is adjustable from 45 to the nominal output frequency in 0.1 Hz increments. Initial Factory Setting is 45 Hz.

Under Frequency Delay is the time span allowed for output frequency to fall below Under Frequency (Hz) before the system will shut down. This is adjustable from 0.01 to 10 seconds in 0.01 second increments. Initial Factory Setting is 10 seconds.

Note that the output frequency is synchronized with the input utility grid during normal operation. Therefore, the Load Output under frequency setpoints should be less than the Utility Input under frequency setpoints to assure coordinated response to utility frequency shifts.

Over Frequency Submenu

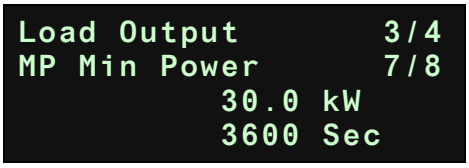


CAUTION	Adjusting the Load Output over frequency setting below the Utility Input under frequency setting may result in the Hybrid UPS system disconnecting power from the critical load when the Utility grid frequency increases. Only adjust the Load Output over frequency to a value greater than the Utility Input over frequency setting.

Over Frequency submenu shows the system over frequency and associated delay time. If the output frequency rises above this over frequency setpoint for the set delay time, the system will shut down. The frequency is adjustable from 65 Hz down to the nominal output frequency, in 0.1 Hz increments. Initial Factory Setting is 65 Hz. If the output frequency exceeds the Over Frequency setting for the time delay setting, the system will shut down. The time delay is adjustable from 0.01 to 10 seconds in 0.01 second intervals. Initial Factory Setting is 10 seconds.

Note that the output frequency is synchronized with the input utility grid during normal operation. Therefore, the Load Output over frequency setpoints should be greater than the Utility Input over frequency setpoints to assure coordinated response to utility frequency shifts.

MultiPac Minimum Power Submenu



MultiPac Minimum Power submenu shows the minimum power level that a group of Hybrid UPS systems must be able to provide before they switch their load outputs on. The settings cannot be set changed from this submenu, and should be set during commissioning by a Capstone Authorized Service Provider.

The kW setting is the minimum value of total power available from the MultiPac of Hybrid UPS systems before the master commands them into Load State and begins outputting power to the critical load. This setting ensures that the system has enough power output capability before power is allowed to be exported to the load, and should be set to the maximum expected load. Initial Factory Setting is 0 kW.

The timeout period setting establishes the maximum time the MultiPac has to achieve the minimum power setting before the system shuts down automatically. This timeout setting is adjustable from 60 to 3600 seconds in 1 second intervals. Initial Factory Setting is 3600 seconds.

Local Battery Charge Submenu

Hybrid UPS microturbine system may be fitted with its own battery storage system. In this case, the Local Battery Charge submenu controls whether the system begins a battery equalization charge. This can be done when the system is in any of its operating modes, provided there is sufficient net power available to do so. Selecting ENABLE will begin the equalization charge, which can last up to 4 hours. Note that the user must be logged in with the current password to change this setting.

Unit Data Menu

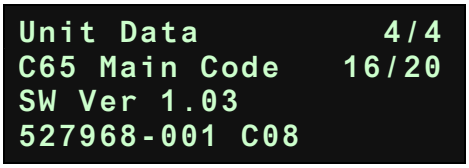
The submenus in the Unit Data menu display real-time data for the MicroTurbine. Descriptive labels and data are contained in the second, third, and fourth lines of the submenu. As in all Display Panel submenus, the first line indicates the top-level menu, in this case the Unit Data menu. Real-time data can also be accessed using CRMS.

The Display Panel submenus related to Unit Data menu are listed below.

NOTE	In the following submenus, the first line always displays the Unit Data top level menu.

Submenu / Function		Description
1/20	System State / Fault Status	System State / Fault Status
2/20	Engine State / Fault Status	Turbine Generator State / Fault Status
3/20	Utility / Load kW	kW Input from Utility and Output to Load
4/20	Utility / Load Frequency	Frequency of Utility and Load Connections
5/20	Utility / Load Volts A	Voltage Phase A of Utility and Load
6/20	Utility / Load Volts B	Voltage Phase B of Utility and Load
7/20	Utility / Load Volts C	Voltage Phase C of Utility and Load
8/20	Utility / Load Amps A	Current Phase A of Utility and Load
9/20	Utility / Load Amps B	Current Phase B of Utility and Load
10/20	Utility / Load Amps C	Current Phase C of Utility and Load
11/20	TET / RPM	Turbine Exit Temp (°C or °F)/ Engine Speed (RPM)
12/20	Fuel Pressure / Fuel %	Fuel Pressure / Fuel Percentage
13/20	Bat Voltage / Bat Current	Battery Voltage / Battery Current
14/20	Bat SOC / Last EQ Charge	Battery State of Charge / Last Equalization Date
15/20	Inlet Temp	Inlet Air Temperature (°C or °F)
16/20	C65 Main Code / Version	C65 Main Software Version Code
17/20	CHP Wtr In Tmp	ICHP Water Inlet Temperature
18/20	CHP Wtr Out Tmp	ICHP Water Outlet Temperature
19/20	CHP Temp Fdbk	ICHP Temperature Feedback
20/20	Hours / Starts	Turbine Running Time / Number of Starts

Below is an example display for a MicroTurbine showing the main software version.



Using a PC with CRMS

Capstone Remote Monitoring Software (CRMS) is available in a User Edition to view data and to provide customers limited control of Hybrid UPS Systems. The software includes minimum PC requirements for proper operation. The CRMS User Manual is embedded in the software help function, and provides intuitive interaction to read data, issue setup and control commands, and view fault history. Once loaded onto a customer PC, CRMS can be connected to a Hybrid UPS system is several ways:

- Through the UPS Controller – the UPS Controller includes industry standard 10BaseT Ethernet ports for connection to a PC. Plugging into one of these ports allows the CRMS software to view each Hybrid UPS system connected to the UPS Controller. The PC can be a laptop that is temporarily connected, or can be any PC on a network that is connected to the UPS Controller's Ethernet Port. Refer to the UPS Controller User Manual (400028) for the location of these Ethernet connections.
- Through the Serial-to-Ethernet Converter in the Hybrid UPS System – each Hybrid UPS system includes a dual port serial-to-Ethernet converter that connects to both the DB9 RS-232 User Interface Port and the DB25 RS-232 Maintenance Interface Ports in the Communications Bay on the back of the MicroTurbine. The serial-to-Ethernet converter uses the Maintenance Port for CRMS connectivity.

Connecting Directly to a Hybrid UPS System

The figures below shows the location of the JUCB communications board within the Communications Bay at the rear of a Hybrid UPS system, and where the Serial-to-Ethernet converter is mounted within the Communciations Bay.

WARNING	The User should NOT open the Power Connection Bay within the User Connection Bay (UCB). Potentially lethal voltages exist inside the Power Connection Bay.

Figure 8 shows the User Interface Port location.

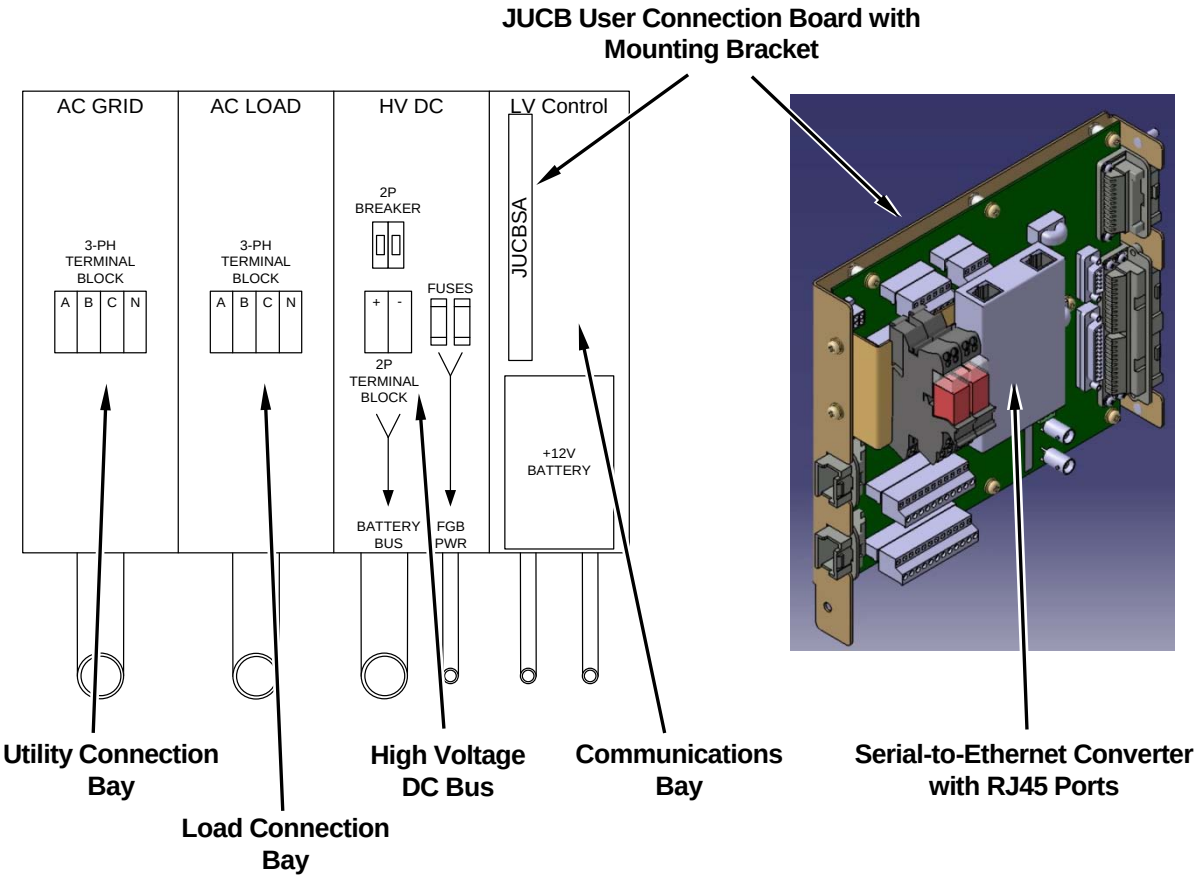


Figure 8. MicroTurbine User Connection Bay with Serial-to-Ethernet Converter

NOTE	The default User Interface Port user password is set to **USR123P**; the user can change it by using the Capstone Remote Monitoring Software on a computer connected either directly to the User Interface Port or through the Serial-to-Ethernet converter. In the event of a lost user password, your Capstone Authorized Service Provider can reset the user password to this default.

MicroTurbine Preventive Maintenance

This section details the preventive maintenance procedures that must be performed on the Capstone MicroTurbine.

WARNING	The MicroTurbine system generates and uses voltage levels that can injure or kill. Obey all safety precautions when you work with or around electrical equipment.

NOTE	Failure to provide proper maintenance will void the MicroTurbine warranty. Users do not perform the following MicroTurbine maintenance procedures, but it is important for users to be aware of them.

Only Capstone Authorized Service Providers can access the inside of the MicroTurbine enclosure (except for accessing the User Connection Board in the UCB/JUCB).

Only Capstone Authorized Service Providers can perform maintenance on the Micro-Turbine components.

Scheduled Maintenance

Table 6 details the preventive maintenance schedules of the C65 Hybrid UPS systems under normal environmental conditions. This information is provided for your reference. Only Authorized Service Providers are permitted to access MicroTurbine components and perform these maintenance tasks.

Table 6. C65 Hybrid UPS package – Gaseous Fuels

Maintenance Interval[3]	Component	Maintenance Action	Comments
24 months	UCB Battery	Replace	
5 years	Electronic Components: ECM, LCM & BCM Power Boards, BCM & ECM Fan Filters, Fans, EMI Filter, Frame PM	Replace	
Per Mfg Instructions	External Energy Storage	Replace	Refer to manufacturer's requirements for the energy storage system being used
4,000 hours	Engine Air Filter	Inspect	Replace if required - see Note 1
	Electronics Air Filter	Inspect	Clean if necessary - see Note 1
	Fuel Filter Element (External)	Inspect	Replace if required - see Note 1
	Fuel System	Leak Check	Refer to "Gaseous Fuel Fittings and Components" section below for recommended procedure
8,000 hours	Engine Air Filter	Replace	See Note 1
	Electronics Air Filter	Clean	
	Fuel Filter Element (External)	Replace	See Note 1
	Igniter	Replace	See Note 2
	ICHP Actuator	Replace	
20,000 hours	Injector Assemblies	Replace	
	TET Thermocouple	Replace	
40,000 hours	Engine	Replace	Use Reman or New Engine Replacement

NOTE 1	Filters may require more frequent attention based upon environment, installation, and/or air/fuel quality. Inspect new installations frequently to determine best inspection/ replacement periods for air and fuel filters.
NOTE 2	Load profiles with frequent onloads and offloads may require more frequent igniter replacement due to igniter operation during injector switching.
NOTE 3	Months and Years are elapsed time. Hours are "Engine Hours," as recorded by each Hybrid UPS system.

Preventive Maintenance Items

Preventive maintenance activities for the MicroTurbine Inlet Filter, External Fuel Filter, and for the Battery Packs are described in the following paragraphs.

MicroTurbine Inlet Air Filter

CAUTION	The MicroTurbine requires clean, dust free air for operation. Do not operate the MicroTurbine without the inlet air filter in place or damage to the equipment can occur.

The engine air inlet filter should be inspected periodically to ensure unrestricted flow of clean combustion and cooling air to the generator and turbine engine. The recommended interval for this inspection is every 4,000 hours of operation or annually, based on clean environment operation.

Outdoor operation, especially in areas subject to wind and airborne dirt or dust, will require a significant reduction in this interval. If the MicroTurbine is operated under unusual conditions, the filters should be checked more frequently to determine a site-specific service interval. Filters may require more frequent attention based upon environment, installation, and/or air quality.

If specifically permitted by the Capstone Authorized Service Provider, the end user can replace the inlet air filter element. The Capstone Authorized Service Provider will provide instruction and oversight.

External Fuel Filter

WARNING	MicroTurbine fuel is flammable and explosive. An explosion can cause death or injury to personnel and/or damage to equipment. No open flame or smoking is allowed near the MicroTurbine.

The optional external fuel filter element should be replaced periodically to ensure unrestricted flow of clean fuel to the MicroTurbine. This is necessary for MicroTurbine optimal performance. The recommended interval for this replacement is every 8,000 hours of operation. The service interval is based on typical clean fuel supplies found in the United States. Filters may require more frequent attention based upon environment, installation, and/or fuel quality.

If specifically permitted by the Capstone Authorized Service Provider, the end user can replace the external fuel filter element. The Capstone Authorized Service Provider will provide instruction and oversight.

Battery Maintenance

Consult the appropriate user manuals for the external energy storage system. Batteries require special consideration for storage and charging. Follow the manufacturer's instructions for proper storage, handling, and charging.

Warranty

Each MicroTurbine ships with a standard warranty. Extended warranties are available. Contact your Authorized Service Provider for details on Capstone warranty terms and conditions.

Troubleshooting

WARNING	The MicroTurbine system produces and contains high voltage. High voltage can injure or kill. Obey all safety procedures when you work around electrical equipment. **Only Capstone Authorized Service Providers are permitted access to the inside of the enclosure.**

This section details basic troubleshooting procedures and steps that the user can perform on the Capstone MicroTurbine without accessing the inside of the enclosure. Only Capstone Authorized Service Providers are permitted access to the inside of the enclosure.

Incidents

The MicroTurbine continuously monitors a wide variety of parameters both internal and external to the system. An **incident** occurs whenever a measured parameter falls outside prescribed limits. Incidents include (but are not limited to) low fuel pressure, utility interruptions, and utility over voltages.

Incident System Severity Levels

When the system detects an incident, it may take one of several actions, depending on the system severity level (SSL). Actions range from simply noting the occurrence and continuing to operate, to immediate shutdown of the system. The action taken depends upon the severity of the incident. The system will attempt a restart only if the severity of the incident will allow it.

Depending on the parameter and the magnitude of the incident, the event is classified as either a warning or a fault.

A **warning incident** is a condition that is outside normal operating parameters, but which does not require a system shut down.

A **fault incident** is a condition under which the system shuts down to prevent possible damage to the MicroTurbine or unsafe operating conditions.

Incident Display Format

When an incident occurs, the Display Panel displays a fault description (e.g., **Internal Fault**) and the fault code (e.g., **10214**). This incident message appears on line three of the System State Fault Status submenu of the Unit Data menu (refer to page 52) as shown in the following example.

```
Unit Data          4/4
System STAND BY   1/20
Internal Fault   10214
```

The fault code is a number up to five digits in length that, along with the fault code description, helps the Capstone Authorized Service Provider determine the cause of the incident. Some fault codes can be useful to the operator, as they indicate common conditions that can occur in system. Table 7 shows a list of common protective relay faults. Utility grid events such as these will cause the Hybrid UPS systems to go into Emergency Mode.

Table 7. List of Common Protective Relay Fault Codes

Type of Fault	Load LCM Codes	Grid LCM Codes
Overvoltage Phase A	10008	10208
Overvoltage Phase B	10009	10209
Overvoltage Phase C	10010	10210
Undervoltage Phase A	10011	10211
Undervoltage Phase B	10012	10212
Undervoltage Phase C	10013	10213
SW Overcurrent Phase A	10014	10214
SW Overcurrent Phase B	10015	10215
SW Overcurrent Phase C	10016	10216
SW Overcurrent Phase N	10017	10217
Under Frequency	10018	10218
Delta Frequency	10019	10219
Over Frequency	10020	10220
Fast Overvoltage	10038	10238
Fast Undervoltage	10039	10239
Fast Overvoltage Phase A	10047	10247
Fast Overvoltage Phase B	10048	10248
Fast Overvoltage Phase C	10049	10249
Fast Undervoltage Phase A	10050	10250
Fast Undervoltage Phase B	10051	10251
Fast Undervoltage Phase C	10052	10252
Fast Under Frequency	10053	10253
Fast Over Frequency	10054	10254

Incident Records

When an incident occurs the system records a snapshot of conditions at that time, called an Incident Record. Several incidents can occur in quick sequence, and the MicroTurbine will continue to operate or shut down depending on the severity of the incident(s).

The Incident Record can only be accessed by an Authorized Service Provider, using CRMS. The Incident Record contains the incident name, incident code number, date and time of the incident, and conditions of the turbine at the time of the incident. Some examples of the data contained in the incident record are as follows:

- Cumulative number of starts
- Output power
- Engine speed
- Turbine exit temperature
- Fuel device command
- Ambient temperature
- Voltage and current on each phase
- Frequency
- DC bus and power supply voltage
- Several internal system temperatures

Isolation Messages

The Incident Record also contains an Isolation Message that describes the type of incident and if it is a Warning or a Fault. The Isolation Messages are listed below and described in the following paragraphs.

- Internal Warning or Fault
- Fuel Warning or Fault
- Grid Warning or Fault
- Lo-Temp Warning or Fault
- Hi-Temp Warning or Fault
- Hi-Alt Warning
- E-Stop Fault
- User Connection Fault

Internal

An Internal incident is one that is within a major subsystem of the MicroTurbine and is not recoverable by the user. In the case of an Internal Fault, the user should reboot the system. If unsuccessful in restoring normal operation, a Capstone Authorized Service Provider will be required to initiate repair of the MicroTurbine.

Fuel

The user should initially check the fuel supply to the MicroTurbine. Verify that the shut off valve is open. Ensure the line has the correct fuel pressure. Check the optional external filter to ensure that it is not blocked. If the problem persists, call your Capstone Authorized Service Provider.

Grid

This event is likely to be due to an electric utility grid disturbance. Check all breakers and fuses to ensure they are not tripped before troubleshooting. The Hybrid UPS system will continue to supply power to the critical load while operating in Emergency Mode, even if the utility power source is unavailable. It will also automatically reconnect to the utility source when the utility power returns to a stable condition and the Hybrid UPS system has transitioned through its utility reconnect delay. If the system does not reconnect to the utility power source after utility power has been restored, call your Capstone Authorized Service Provider.

Lo-Temp/Hi-Temp/Hi-Alt

Generally, these incidents are due to ambient conditions that are outside the design envelope of the MicroTurbine. Possible solutions would be to adjust the room temperature, ensure that adequate ventilation is provided, and verify that the air input and exhaust are not obstructed. Continued operation under these conditions may affect operation and cause damage to the MicroTurbine.

E-Stop

If the event display reads **MANUAL E-STOP**, fix the original problem that initiated the E-Stop, as this fault must be cleared before it is safe to resume operation. Next, check the optional emergency stop button and verify that it has been activated. If it has, reset the button, cycle power off to the MicroTurbine for 30 seconds, and turn the power back on. The Manual E-Stop fault should clear, and the system should resume operation. If it does not, call your Capstone Authorized Service Provider.

User Conn (User Connection)

User Connection incidents can be due to incorrect Grid Connect / Stand Alone settings, mode transition faults when in Dual Mode operation, or to indicate a possible problem with external equipment connected to the MicroTurbine, such as the Gas Pack accessory.

Basic Troubleshooting Procedures

Basic Troubleshooting procedures are presented in the following paragraphs.

WARNING	Users do not perform some of the following MicroTurbine troubleshooting procedures, but it is important for users to be aware of them. Only Capstone Authorized Service Providers are permitted access to the inside of the enclosure. Users are permitted to open the User Connection Bay to access the User Interface Port.

No Lights on Display Panel

If no lights are present on the Display Panel, troubleshoot as follows:

WARNING	Only Capstone Authorized Service Providers can perform the following troubleshooting steps.

1. If no utility power is available, make sure the external battery power is available and then press the **BATT START** button on the Display Panel.
2. If utility power is made available, the system should wake up automatically.

No Attempt to Start after ON Command

If no attempt is made to Start, after an **ON** Command, troubleshoot as follows:

1. Verify that the current communication device (Display Panel, User Interface Port, or Maintenance Interface Port) is the control device. Refer to Control Device Authority and Priority on page 25.
2. Verify that **ON** command is consistent with the currently active dispatch mode. Refer to the section on Display Panel Menus for more data.

Start Attempt Fails

If a Start Attempt fails, troubleshoot as follows:

1. If the system attempts but fails to start, an incident code will be registered as described in the previous sections.
2. The troubleshooting procedure is the same as for Unexpected Shut Down or Warning in the next section.

Low Power Output

If Low Power Output is perceived, troubleshoot as follows:

1. Check your inlet fuel supply. Verify that the fuel isolation valve is open, and that the inlet fuel line has the correct fuel pressure.
2. Check your external fuel filter. Verify that the external fuel filter (if installed) is not blocked.
3. Check your inlet airflow, ventilation, and exhaust airflow. Verify that the inlet airflow and the exhaust airflow are not obstructed.
4. Check your ambient operating conditions and verify the expected power output due to temperature, altitude and other derating factors. Verify that ambient conditions are not outside the MicroTurbine design envelope.

Unexpected Shut Down or Warning

When a warning incident occurs, no action is required by the user. When a fault incident occurs, the troubleshooting steps are as follows:

1. Attempt to restart. If unsuccessful, then verify the fuel, air, and electrical supply to the MicroTurbine.
2. Attempt to restart. If unsuccessful, then enter the user password and reboot the system through the Display Panel.
3. Attempt to restart. If unsuccessful, then cycle the power by shutting off power to the system, waiting 30 seconds, and turning the power back on.
4. Attempt to restart. If unsuccessful, then note the event number listed on the Display Window, and then call your Capstone Authorized Service Provider for assistance.

When required, your Capstone Authorized Service Provider will determine whether the event noted requires a service call or if the user can perform fault correction on site. Generally, the Service Provider will initiate a service call for Internal Fault codes. In most other cases, the Service Provider will recommend a possible course of action to return the MicroTurbine to operational status.

Product Support

Capstone Turbine Corporation is dedicated to the concept of quality to the owners and users of every MicroTurbine. Your MicroTurbine should operate without trouble. If you require maintenance support or other technical assistance, **please contact your Capstone Authorized Service Provider**.

Capstone Technical Support can assist you by providing contact data for your Capstone Authorized Service Provider.

Fill in this record with information about your Capstone Authorized Service Provider to allow easier access.

Capstone Authorized Service Provider Contact Information	
ASP Contact Name	
Address	
Telephone	
Facsimile	
E-mail	

The following information will help your Authorized Service Provider assist you.

System Information	
MicroTurbine Model No.	
System Serial No.	
Fuel Type	
Modem Phone No.	
Options Installed, and any configuration data	

CUSTOMER SATISFACTION

We would love to hear feedback about your experience with our products.
Please send e-mail to: **comments@capstoneturbine.com**

– Maintenance Log –

Event	Date	Hours	Starts
Commissioning			

Reference Documents

Refer to the following table for a list of Capstone reference documents, as required.

Document Part No	Description
400028	Hybrid UPS Controller User Manual
410013	CRMS User Manual
410081	Hybrid UPS Controller Technical Reference
410048	Model C65 Performance Technical Reference
410033	Protective Relay Functions Technical Reference
480014	Model C65 Integrated CHP Application Guide

Capstone Contact Information

If you have additional questions, please contact:

Capstone Applications

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E-mail: applications@capstoneturbine.com

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